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Management of Peatland Shrub- and Forest-dominated Communities for Threatened and Endangered Species

by
Kevin Robertson, Mary G. Harper, and Mike Woolery

Plant communities found on peatland soils include forests, basin shrublands, and seepage communities. The ecology and management of six communities are reviewed, with an emphasis on land uses associated with Department of Defense (DoD) installations. Peatland plant communities in the southeastern United States are important to landscape and regional biodiversity because they are often the only natural areas that have not been converted to urban or agricultural uses, and they support several threatened, endangered, and sensitive species (TES). Several of these plant communities are rare due to alterations in fire and hydrology over large expanses of the region.

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Foreword

This study was conducted for the Strategic Environmental Research and Development Program (SERDP) under Work Item ES8, "Regional Guidelines for Managing Threatened and Endangered Species Habitats." The technical monitor was Dr. Femi A. Ayorinde, Cleanup and Conservation Program Manager, SERDP. Mr. Bradley P. Smith is the Executive Director, SERDP.

The work was performed by the Natural Resource Assessment and Management Division (LL-N) of the Land Management Laboratory (LL), U.S. Army Construction Engineering Research Laboratories (CERL). Ms. Harper was employed as a Research Associate under an interagency agreement with the U.S. Forest Service, Rocky Mountain Range and Forest Experiment Station, and Colorado State University. Ms. Harper was responsible for community classification, while Mr. Woolery and Mr. Robertson provided information on community impacts and management. Ms. Ann-Marie Trame, CERL principal investigator, coordinated preparation of this report. Information on animal species was the responsibility of Dr. Richard A. Fischer, and overall coordination for the work unit was the responsibility of Mr. Chester O. Martin, both from the Natural Resources Division (NRD), Environmental Laboratory (EL), U.S. Army Engineer Waterways Experiment Station (WES), Vicksburg, MS. Dr. Harold E. Balbach is Acting Chief, CECER/LL-N. Dr. John T. Bandy is Operations Chief, CECER-LL; and Dr. William Severinghaus is the responsible Technical Director, CECER-LL. The CERL technical editor was Gloria J. Wienke, Technical Information Team.

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Background

Plant communities found on peatland soils include forests, basin shrublands, and seepage communities. Peatland plant communities in the southeastern United States are important to landscape and regional biodiversity because they are often the only natural areas that have not been converted to urban or agricultural uses, and they support several threatened, endangered and sensitive species (TES). Several of these plant communities are rare themselves, due to alterations in fire and hydrology over large expanses of the region. Many of these communities can be found on Department of Defense (DoD) installations in the southeast. The ecology and management of six different but similar communities are reviewed here with an emphasis on land uses associated with DoD installations.

Management approaches to protecting TES and natural plant communities are often designed to address immediate and local problems (M. Imlay, Natural Resource Specialist, Army National Guard Bureau, professional discussion, 18 August 1995). Although this approach can be rewarding and effective for an individual installation, it precludes any organized understanding of land use impacts, or sharing of lessons learned, and can sometimes lead to repeated, inefficient efforts to solve similar problems throughout a region of the country. Duplication of effort needs to be reduced or eliminated.

This report constitutes one in a series that is the product of an interlaboratory effort between the U.S. Army Construction Engineering Research Laboratories (USACERL) and the U.S. Army Engineer Waterways Experiment Station (WES) to generate habitat-based management strategies for TES on DoD lands in the southeastern United States (Strategic Environmental Research and Development Program [SERDP] work unit "Regional Guidelines for Managing T&E Species Habitats"; Martin et al. 1996). This effort is directed at developing strategies to manage TES and their habitats on a plant community basis, using methods that apply to multiple species and that apply to military training lands across the southeastern United States. Any increase in understanding of the habitat requirements of listed TES will help training and natural resource personnel to comply with the Endangered Species Act (ESA), while avoiding restrictions on the military mission. Furthermore, the results detailed in this report suggest a great deal of additional effort is required before the management process can largely be driven by solid scientific information (as required by the ESA).

Objectives

The objectives of this research were to compile known information, identify gaps in knowledge, and stimulate future research efforts on the potential positive and negative effects of landscape planning, silviculture, military training, and other resource-based activities on six peatland communities that serve as high-quality habitat for TES on military lands in the southeastern United States.

This SERDP work unit, in particular, was undertaken to reduce duplication of effort in conservation of TES using habitat in peatland shrub- and/or forest-dominated communities. It is hoped that this review of information may be used to improve the ecological and economic effectiveness of TES habitat management. By understanding the ecological requirements of TES and the environmental resilience or sensitivity of the six peatland communities discussed here, installations acquire increased control over TES management and land use decisions.

Approach

To identify potential impacts and management options to mitigate those impacts, researchers reviewed the available literature and conducted interviews with community ecologists throughout the southeastern United States, with an emphasis on interviewing those people who have been involved in TES and plant community survey work on military installations. Site visits were made to military installations. Potential impacts were also discussed with military natural resources personnel, botanists, community ecologists, and military contractors such as The Nature Conservancy (TNC) and state Natural Heritage Program (NHP) staff. Information also was acquired from installation TES survey reports in which impacts and management were addressed. Land Condition Trend Analysis (LCTA) reports, Land Rehabilitation and Maintenance (LRAM) data, and academic and Federal agency literature on logging and recreational impacts to plant communities were also used.

Scope

Within the context of the larger DoD mission, TES populations can be maintained through the following framework: (1) identify mission requirements, (2) identify TES requirements, (3) identify ideal compromises for meeting both TES and mission requirements, and (4) pursue these compromises and develop realistic, workable approaches. The fourth step should be executed through professional management of TES populations, at the installation level, to reduce restrictions on the military mission. This document partially contributes to the total TES and land-management process. It provides information to assist in identifying the needs of TES (step 2), and perhaps will assist in identifying options for compromise as well (step 3). The content of this report is not intended to provide the "bottom line" for management of TES on military lands — only to provide information from literature review for the consideration of installation land managers.

This report focuses on plant communities because they provide habitat for numerous species. By managing at the community or ecosystem level, DoD has the opportunity to conserve multiple TES simultaneously. Plant communities are less ambiguous entities than complete ecosystems, and have been described and cataloged for many decades by ecologists and biogeographers. They provide a useful basis for understanding and managing the natural systems that support military training and other land uses.

Peatland communities support multiple uses, including DoD training and testing, TES conservation, and forest commodities (e.g., timber) production. This document provides a review of wetland ecology and recommended management practices for peatland shrub- and forest-dominated communities. It is intended to provide current information for management on military installations that is compatible with the military mission (e.g., training). Where feasible, recommendations mimic natural disturbance patterns and provide suitable habitat for the diversity of species that inhabit the community, with an emphasis on TES.

A range of management options was considered for areas that trainers and resource managers recognize as potential endangered species habitat. These options are not intended to constrain military training. Rather, management options were developed within the context of training requirements, and should be considered only to the extent they are compatible with training. Many of the more restrictive land use options identified in this report apply to lands already protected due to their sensitive nature (forested wetlands). Training will continue to be the primary land use concern, with training-land decisions being made daily based on whatever information is available at the time. Flexibility in management options identified in this and related reports will enable land managers to make more informed decisions and effectively support the training mission. Moreover, while management options in this report are not intended to be applied across entire DoD installations, they are presented as potential tools consistent with an ecosystem approach and support healthy, functional communities.

Mode of Technology Transfer

This report is to be used by DoD natural resource policymakers, installation land managers, and the natural resources research community, in conjunction with associated documents produced under this SERDP work unit (e.g., Trame and Harper 1997) Harper et al. 1997; and by Trame and Tazik (1995) to (1) develop ecosystem-compatible approaches to describe natural communities and TES habitat within the context of military land management, (2) evaluate military-related effects on those communities, (3) develop community-based strategies for supporting both military land use and TES habitat management, and (4) develop management solutions for military impacts to natural communities when management for TES habitat is a priority.

This report is available on the CERL web page at http://www.cecer.army.mil

2 Overview of the Peatland Communities

The plant communities included in this report can be categorized as forest/woodland types: Atlantic white cedar (AWC) forest, pond pine woodland, cypress domes, streamhead pocosins and bay forest; and basin shrub-dominated types: low, high, and depression pocosins. They all share characteristic peatland soils, and may succeed each other through time and space due to the influence of hydroperiod and fire return interval (Figure1). Consequently, these communities often form a mosaic on the landscape and are connected by hydrologic and fire processes, and wildlife movements (Figure 2). The ecotones near cypress domes and streamhead pocosins, and portions of high-quality basin pocosins, are important sites dominated by a rich herbaceous layer that includes many rare plants. Although these sites are ecologically similar to bogs, larger expanses of herbaceous seeps and bogs on peatland soils were considered separately by Harper et al. (1997). More complete ecological descriptions of the communities summarized below can be found in the appendices.

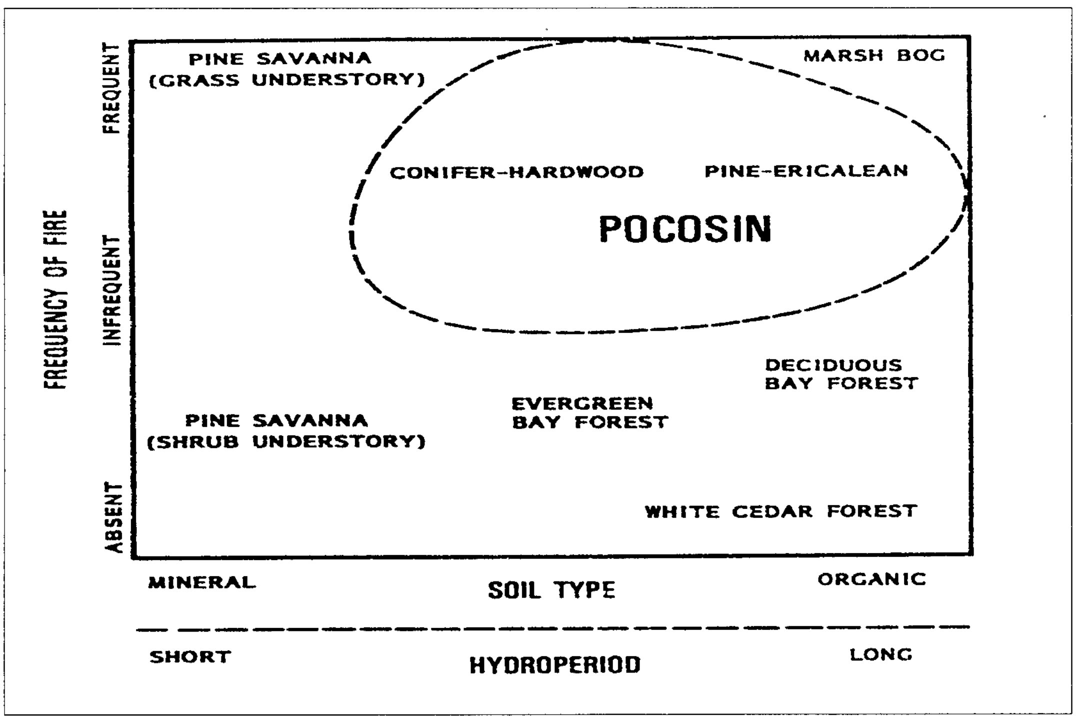

Figure 1. Proposed relationships among vegetation types, hydroperiod, and fire in pocosin habitats. (Source: Sharitz and Gibbons, 1982.)

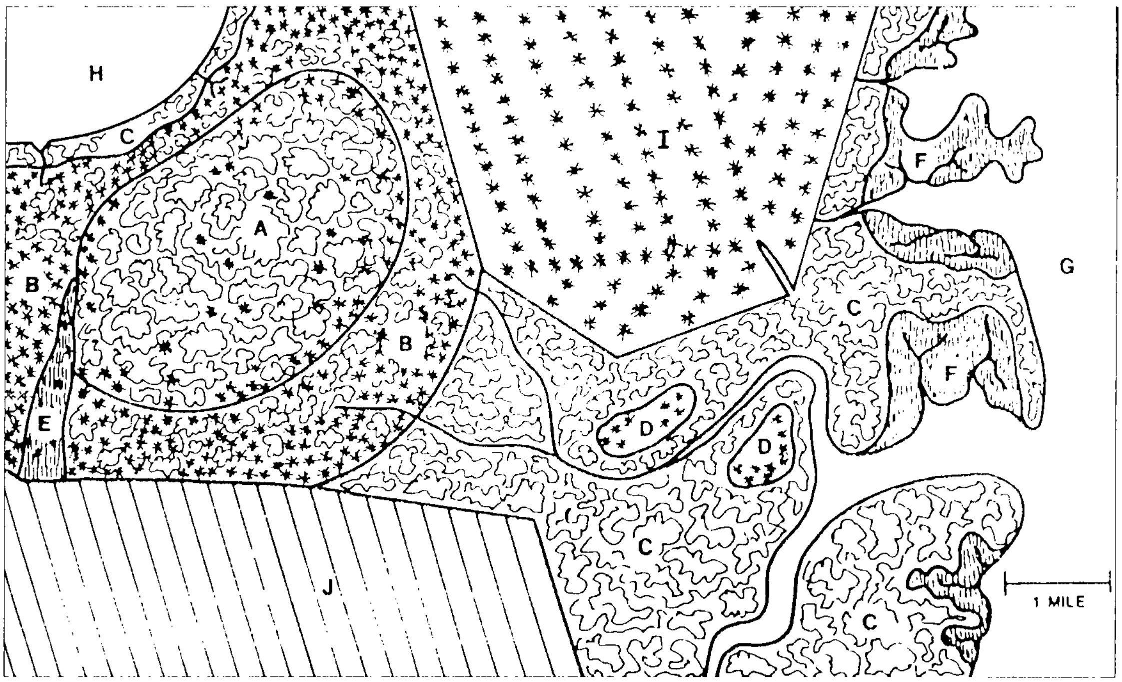

Figure 2. Diagram relating to adjacent ecosystems: (A) short pocosin, (B) tall pocosin, (C) gum-cypress swamp forest, (D) Atlantic white cedar swamp forest, (E) savannah, (F) marsh, (G) estuary, (H) lake, (I) pine plantation, (J) agricultural field. (Source: Ash et al 1983.)

Bay Forests

The bay forest community type (Figure 3) occurs on the Atlantic coastal plains from Virginia south to Florida, and west to eastern Texas and Arkansas (Christensen 1988, Landaal 1991a). Examples of bay forests occur on 12 military installations in the southeastern United States (Table 1). Bay forests may generally be divided into those that occur on seepage slopes and those that occupy basins or non-alluvial wetlands. Those on seepage slopes share many physical characteristics with streamhead pocosins and those in basins with the other pocosin types and peatland forests. Community structure is characterized by a dense, short (3 to 10 m in height in the Green Swamp, NC) canopy made up of broad-leaved evergreens, a vine-shrub subcanopy, a dense to somewhat open shrub layer, and a sparse herbaceous layer (Landaal 1991a, Schafale and Weakley 1990). Bay forests are extremely susceptible to fire, and when burned, usually revert to an earlier successional community. The bay forest community is characterized by the canopy dominance of loblolly bay (*Gordonia lasianthus*), sweet bay (*Magnolia virginiana*), and swamp red bay (*Persea palustris*) with other associated species varying across the region (Landaal 1991a, Christensen 1988). In North Carolina, pond pine (*Pinus serotina*), swamp tupelo

Figure 3. Bay forest in North Carolina.

Table 1. Known, reported occurrences of peatland communities on military installations in the southeastern United States.

State	Branch	Installation	Community type	Community name as provided in documents	References
AL	Army	Fort Rucker	Bay forest	Bay Swamp	Mount and Diamond 1992
FL	Air Force	Eglin Air Force Base (AFB)	Bay forest	Baygall	Florida Natural Areas Inventory (FNAI) 1994a
		Eglin AFB	Pocosin	Seepage Slope (Streamhead Pocosin)	FNAI 1994a
		Eglin AFB	Cypress Dome	Dome Swamp	FNAI 1994a
		Hurlburt Field sub: Eglin AFB	Pocosin	Titi Ponds	LABAT-ANDERSON INC. 1994
		Tyndall AFB	Bay forest	Baygall	FNAI 1994b

State	Branch	Installation	Community type	Community name as provided in documents	References
	Army	Camp Blanding	Bay forest	Bay Swamp	Information sent to authors by Robert Brozka*, 1994
	Navy	Naval Air Station (NAS) Pensacola	Bay forest	Bay Swamp	excerpt from Natural Resources Management Plan, sent to authors by Tom Burst**, 1995
		Naval Air Station (NAS) Pensacola	Pond Pine Woodland	Pond Pine Dominated Flatwoods (Wet Flatwoods)	excerpt from Natural Resources Management Plan, sent to authors by Tom Burst, 1995
		Naval Air Station (NAS) Pensacola	Pocosin	Titi Swamp	excerpt from Natural Resources Management Plan, sent to authors by Tom Burst, 1995
		NAS Whiting Field	Bay forest	Bayheads	excerpt from Natural Resources Management Plan, sent to authors by Tom Burst, 1995
		NAS Whiting Field	Atlantic White Cedar Forest	Atlantic White Cedar Forest	excerpt from Natural Resources Management Plan, sent to authors by Tom Burst, 1995
		NAS Whiting Field	Pocosin	Titi Depressions	excerpt from Natural Resources Management Plan, sent to authors by Tom Burst, 1995
		Cecil Field NAS	Cypress Dome	Cypress domes	excerpt from Natural Resources Management Plan, sent to authors by Tom Burst, 1995

* Robert Brozka is the Assistant Director for Field Operations, Center for Ecological Management of Military Lands, Colorado State University, CO.

** Tom Burst is Fish and Wildlife Biologist, Southern Division, Naval Facilities Engineering Command, North Charleston, SC.

State	Branch	Installation	Community type	Community name as provided in documents	References
GA	Army	Fort Stewart	Bay forest	Bay Forest	The Nature Conservancy (TNC) 1995
		Ft. Stewart	Cypress Dome	Dome Swamp	TNC 1995
LA	Army	Camp Villerie	Bay forest	Bayhead Swamp	TNC 1993
		Fort Polk	Bay forest	Bayhead Swamp	Hart and Lester 1993
MS	Army	Camp Shelby	Bay forest	Bay Forest	Information sent to authors from Ron Wieland*, 1994
NC	Air Force	Dare County AFR	Bay forest	Bay Forest	Fussel et al. 1995
		Dare County Bombing Range	Atlantic White Cedar Forest	Peatland Atlantic White Cedar Forest	North Carolina Natural Heritage Program (NCNHP) and The Nature Conservancy (TNC) 1995
		Dare County Bombing Range	Pond Pine Woodland	Pond Pine Woodland	NCNHP and TNC 1995
		Dare County Bombing Range	Pocosin	Low Pocosin, High Pocosin	NCNHP and TNC 1995
	Army	Camp Mackall and Fort Bragg	Atlantic White Cedar Forest	Peatland Atlantic White Cedar Forest, Streamhead Atlantic White Cedar Forest	Russo et al. 1993
		Camp Mackall and Fort Bragg	Pocosin	Small Depression Pocosin, Streamhead Pocosin	Russo et al. 1993
		Sunny Point Military Ocean Terminal (MOT)	Pond Pine Woodland	Pond Pine Woodland	Information sent to authors from Mike Schafale**, 1994
	Marine Corps	Marine Corps Air Station (MCAS) Cherry Point	Pond Pine Woodland	Pond Pine Woodland	LeBlond, Fussell, and Braswell 1994b

* Ron Wieland is the Ecologist with the Mississippi Department of Wildlife, Fisheries and Parks, Jackson, MS.
** Michael Schafale is the Community Ecologist with the North Carolina Natural Heritage Program.

State	Branch	Installation	Community type	Community name as provided in documents	References
		Marine Corps Base (MCB) Camp Lejeune	Atlantic White Cedar Forest	Peatland Atlantic White Cedar Forest	LeBlond, Fussell, and Braswell 1994a,c
		Marine Corps Base (MCB) Camp Lejeune	Pond Pine Woodland	Pond Pine Woodland	LeBlond, Fussell, and Braswell1994a,c
		MCB Camp Lejeune	Pocosin	Low Pocosin, High Pocosin, Small Depression Pocosin, Streamhead Pocosin	LeBlond, Fussell, and Braswell1994a,c
SC	Army	Fort Jackson	Pocosin	Low Pocosin, High Pocosin	Information sent to authors by Bert Pittman*, 1995
VA	Army	Fort A.P. Hill	Bay forest	Oligotrophic Saturated Forest	Fleming and van Alstine 1994a
		Fort A.P. Hill	Pond Pine Woodland	Oligotrophic Saturated Woodland	Fleming and van Alstine 1994a
		Fort A.P. Hill	Pocosin	Oligotrophic Scrub	Fleming and van Alstine 1994a
		Fort Picket	Pocosin	Oligotrophic Scrub	Fleming and van Alstine 1994b

* Bert Bittman is the Botanist with the North Carolina Natural Heritage Program.

(*Nyssa biflora**), red maple (*Acer rubrum*), loblolly pine (*Pinus taeda*), and Atlantic white cedar (*Chamaecyparis thyoides*) may be significant components of the canopy and sub-canopy in addition to the dominant bay species (Schafale and Weakley 1990). In Florida, pond pine, slash pine (*Pinus elliottii*), longleaf pine (*Pinus palustris*), and bald cypress (*Taxodium distichum*) occur in bay forests. Canopy dominants in Texas bay forests include swamp laurel oak (*Quercus laurifolia*), black gum (*Nyssa sylvatica***), sweet bay, yaupon (Ilex vomitoria), and red maple (Christensen 1988). In Louisiana, the canopy is similar to that in Texas, with the addition of pond cypress (*Taxodium ascendens*), slash pine, and longleaf pine. The shrub layer can be diverse and may include titi (*Cyrilla racemiflora*), fetter-bush (*Lyonia lucida*), sweet gallberry (*Ilex coriacea*), bitter gallberry (*I. glabra*), evergreen bayberry (*Myrica heterophylla*), black highbush blueberry (*Vaccinium atrococcum*), highbush blueberry (*V. corymbosum*), zenobia (*Zenobia pulverulenta*) (Christensen

* The original source uses *Nyssa sylvatica var. biflora* as the name for swap tupelo. The current scientific name *Nyssa biflora (Walt.)* is used in all instances in this report.

** The original source uses *Nyssa sylvatica var. sylvatica* as the name for black gum. The current scientific name, *Nyssa sylvatica* (Marsh.), is used in all instances in this report.

1988), wax myrtle (*Myrica cerifera*), male-berry (*Lyonia lugustrina*), leucothoe (*Leucothoe axillaris, L. racemosa*), Virginia willow (*Itea virginica*), red chokeberry (*Sorbus arbutifolia*), possum-haw viburnum (*Viburnum nudum*), poison sumac (*Rhus vernix*), sweet pepperbush (*Clethra alnifolia*), hazel alder (*Alnus serrulata*), American snowbell (*Styrax americana*), summer azalea (*Rhododendron serrulatum*), wild azalea (*Rhododendron oblongifolium*) (Smith 1988), and sparkle berry (*Vaccinium corymbosum*) (Ewel, Davis, and Smith 1989). Vines, including greenbriar (*Smilax* spp.), Carolina jessamine (*Gelsemium sempervirens*), and Virginia creeper (*Parthenocissus quinquefolia*) are important components of bay forests (Christensen 1988). Herb species include netted chainfern (*Woodwardia areolata)*, cinnamon fern (*Osmunda cinnamomea*), and royal fern (*Osmunda regalis*) (Landaal 1991a, Christensen 1988). Appendix A gives a detailed ecological description of bay forest communities.

Atlantic White Cedar Forests

Atlantic white cedar (AWC) forests (Figure 4) occur on peatlands throughout the Coastal Plain, occurring in a narrow coastal range 50 to 130 miles wide from southern Maine to northern Florida and west to southern Mississippi. Table 1 lists the installations where AWC communities can be found. AWC forests are found on shallow, frequently flooded organic soils on interstream flats and peat-filled Carolina bays and swales (Weakley and Schafale 1991). This plant community is dependent on fire for persistence; it requires open conditions with little to no competing vegetation in order to regenerate. This condition is best created through stand-killing crown fires at intervals of 25 to 250 years. In the presence of such a fire regime, this community exhibits a dense, even-aged canopy dominated by AWC, with a relatively open shrub and herb layer (Landaal 1991b). AWC does not form even-aged stands in areas without the appropriate type of catastrophic disturbance (Clewell and Ward 1987). In these cases, AWC shares dominance with several other species, and a more dense shrub layer forms (Christensen 1988). In mixed stands, characteristic subdominants include red maple, sweet bay, and swamp tupelo (Landaal 1991b). The shrub layer is often dominated by sweet pepperbush and highbush blueberry (Landaal 1991b), but can also include fetter-bush, sweet gallberry, bitter gallberry, and red bay (*Persea borbonia*; Christensen 1988). Peat moss (*Sphagnum sp.*) and Virginia chainfern (*Woodwardia virginica*) are important species in the herb layer (Christensen 1988), as are partridge berry (*Mitchella*

Figure 4. Old-growth Atlantic White Cedar forest in North Carolina.

repens) and poison ivy (*Toxicodendron radicans*[*]) (Landaal 1991b). Appendix B gives a detailed ecological description of the AWC community.

Pond Pine Woodland

Pond Pine Woodlands (Figure 5) are found on the outer Coastal Plain from Florida to Virginia (Landaal 1991c). There are six known occurrences of pond pine woodlands on military lands in the southeastern United States (Table 1). These communities occur on poorly drained sites over shallow organic soils that undergo temporary flooding (Schafale and Weakley 1990). This community exhibits an open to nearly closed canopy, with a tall (greater than 5 m) dense shrub layer and sparse

[*] The original source uses *Rhus toxicodendron* as the name for poison ivy. The current scientific name, *Toxicodendron radicans*, is used in all instances in this report.

understory (Schafale and Weakley 1990). Highest quality pond pine woodlands are characterized by an understory dominated by cane (*Arundinaria gigantea* or *A. tecta*), which requires burning at intervals of 3 to 5 years. Under fire return intervals of 10 to 20 years, the community experiences a shift in the understory vegetation, from dominance by cane, to shrubs that slowly replace the cane. The pond pine woodland's canopy is dominated by pond pine and may include co-dominant loblolly bay (within its range), sweet bay, red maple, loblolly pine, and AWC in the canopy and understory (Landaal 1991c, Schafale and Weakley 1990). The subcanopy or shrub layer is dominated by titi, fetter-bush, sweet gallberry, and swamp red bay (Landaal 1991c). Common vines are blaspheme vine (*Smilax laurifolia*) and coral greenbriar (*Smilax walteri*) (Landaal 1991c). Herbs are generally nearly absent, but may include Virginia chainfern, netted chainfern and peat moss clumps (Landaal 1991c, Schafale and Weakley 1990). Appendix C gives a detailed ecological description of pond pine woodland communities.

Basin Pocosins

The three basin pocosins, low, high and depression pocsins, are discussed together because they grade into one another in the landscape, and/or they have similar physical and floristic characteristics. Low pocosin communities occur on the coastal

Figure 5. Pond Pine woodland in North Carolina.

plain from Virginia to Florida, but are mostly restricted to the outer coastal plain of North Carolina (Schafale and Weakley 1990). Small depression pocosins are found in isolated areas throughout the coastal plain and sandhills in North and South Carolina (Doyle 1990a, Schafale and Weakley 1990). Eleven military installations in the southeastern United States support basin pocosin communities (Table 1). Low pocosins occur on deeper peat (usually 1 to 5 m deep) than high pocosins (peat depth of 1.5 m or less) (Figure 6); both communities occur on oligotrophic wet sands (Schafale and Weakley 1990). Pocosin communities are seasonally flooded; almost all of the water is received as direct rainfall (Schafale and Weakley 1990). The basin pocosin communities are maintained by fire; natural ignitions are thought to have occurred at 3- to 8-year intervals in areas with the highest species diversity. In the past, fires burned over large areas at a time, and recovery of the vegetation was rapid. In fact, species diversity and productivity are highest following fire. Low pocosins are dominated by shrubs less than 1.5 meters in height, but may include widely spaced, stunted and gnarled pond pine. High pocosins (Figure 7) have a shrub layer ranging from 1.5 to 3 m tall, a subcanopy formed by scattered bay shrubs and hardwood species, and may exhibit an open canopy of pond pine. Small depression pocosins may resemble either low or high pocosins in their physiognomy (Doyle 1990a).

Low pocosins consist of a canopy of widely scattered and stunted pond pine, swamp red bay, loblolly bay, with sweet bay often included. The dense shrub layer is usually dominated by fetter-bush, titi, zenobia, or gallberry. Blaspheme vine or laurel greenbriar is common. Pools or openings dominated by leatherleaf (*Cassandra calyculata*), Walter's sedge (*Carex walteriana*), Virginia chainfern, yellow pitcherplant (*Sarracenia flava*), bushy beardgrass (*Andropogon glomeratus*), peat (*Sphagnum sp.*), and, rarely, cranberry (*Vaccinium macrocarpon*) may occur within the low pocosin (Schafale and Weakley 1990).

In North Carolina, the high pocosin canopy/subcanopy usually consists of pond pine (less than 25 percent cover), swamp red bay, loblolly bay, and sweet bay (Schafale and Weakley 1990). Red maple, swamp tupelo, and sweet gum (*Liquidambar styraciflua*) may also occur across the range of this community (Doyle 1990b). In North Carolina, the shrub layer is dominated by fetter-bush, titi, and zenobia. Regional shrub dominants may also include red bay. Greenbriar and blaspheme vine are also common in high pocosins. Switch cane (*Arundinaria tecta*) may occur. Herbs are generally absent, but in recently burned sites Virginia chainfern and bushy beardgrass may occur (Schafale and Weakley 1990).

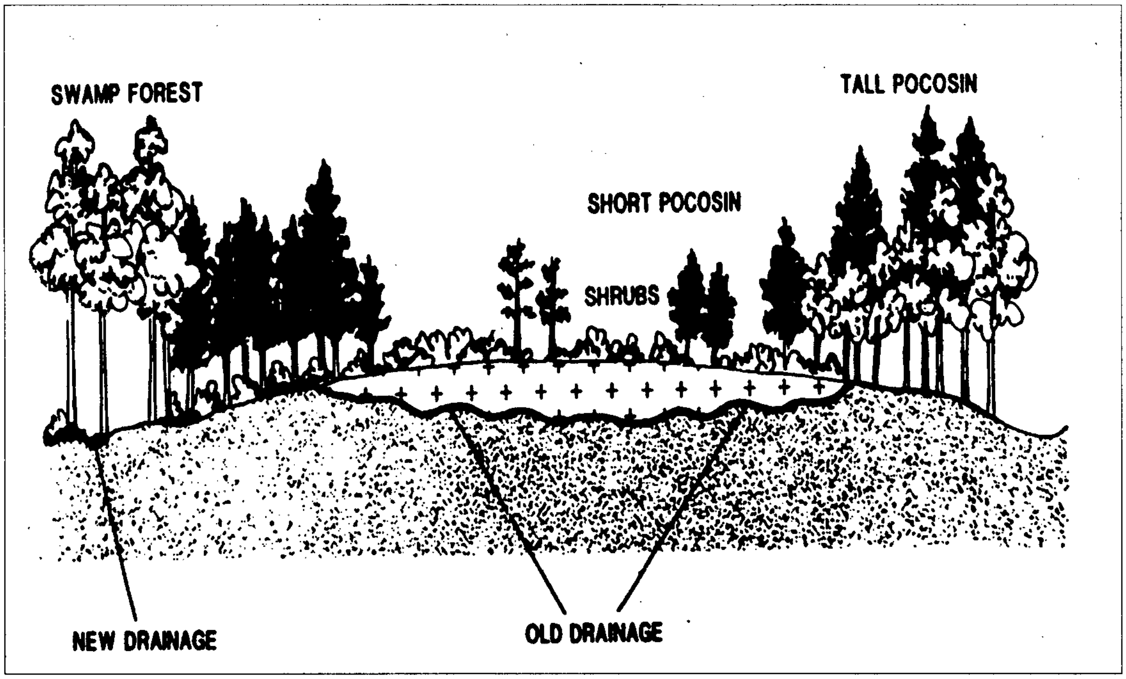

Figure 6. Relationship between pocosin types and depth of peat.

Figure 7. High Pine Pocosin in North Carolina.

Small depression pocosin communities have a sparse to dense canopy that may include pond pine, red maple, swamp red bay, sweet bay, swamp tupelo, pond cypress, loblolly pine, and loblolly bay. The dense shrub layer consists of fetter-bush, titi, bitter gallberry, sweet gallberry, sweet pepperbush, dangleberry (*Gaylussacia frondosa*), and myrtle-leaved holly (*Ilex myrtifolia*), highbush blueberry, and Carolina sheepkill (*Kalmia carolina*); wetter areas may support zenobia and leatherleaf. Blaspheme vine and wild sarsaparilla (*Smilax glauca*) may be common. The sparse herbaceous layer may include cinnamon fern, Virginia chainfern, netted chainfern, and sedge (*Carex spp.*) (Doyle 1990a, Schafale and Weakley 1990). Appendix D gives a detailed ecological description of these pocosin communities.

Streamhead Pocosin

Streamhead pocosins (Figures 8 and 9) occur in scattered locations throughout the upper Coastal Plain and fall-line sandhills from southeastern Virginia to northern Florida and west to southeastern Alabama (Martin 1992). See Table 1 for a listing of streamhead pocosins occurring on military installations in the southeast. Streamhead pocosins occur on wet, acidic soils overlying clay or sand in the headwaters of small streams, flat bottoms, and sometimes seepage slopes (Schafale and Weakley 1990). Streamhead pocosins have historically burned along with the surrounding plant community, which was often longleaf pine sandhills. The edges of the pocosin burn more frequently than the interior, due to a strong gradient in moisture. Many of the species found in the herbaceous layer are adapted to the open light conditions maintained by frequent fire. Infrequently burned streamhead pocosins tend to have greater concentrations of trees and shrubs and fewer herbs than frequently burned examples (Martin 1992).

Streamhead pocosin communities are characterized by having a scattered to very dense canopy, a dense shrub layer, and a less sparse herb layer than other pocosin types (Martin 1992, Schafale and Weakley 1990). The streamhead pocosin canopy consists primarily of pond pine and sweet bay, but may also include slash pine, loblolly pine, swamp red bay, tulip tree (*Liriodendron tulipifera*), red maple, swamp tupelo, black gum, and AWC (Martin 1992). The shrub layer is dominated by titi, buckwheat tree (*Cliftonia monophylla*), and fetter-bush (Martin 1992). In North Carolina, netted chainfern, cinnamon fern, and sedge are typical herbs (Schafale and Weakley 1990). Appendix E gives a detailed ecological description of stream head pocosin communities.

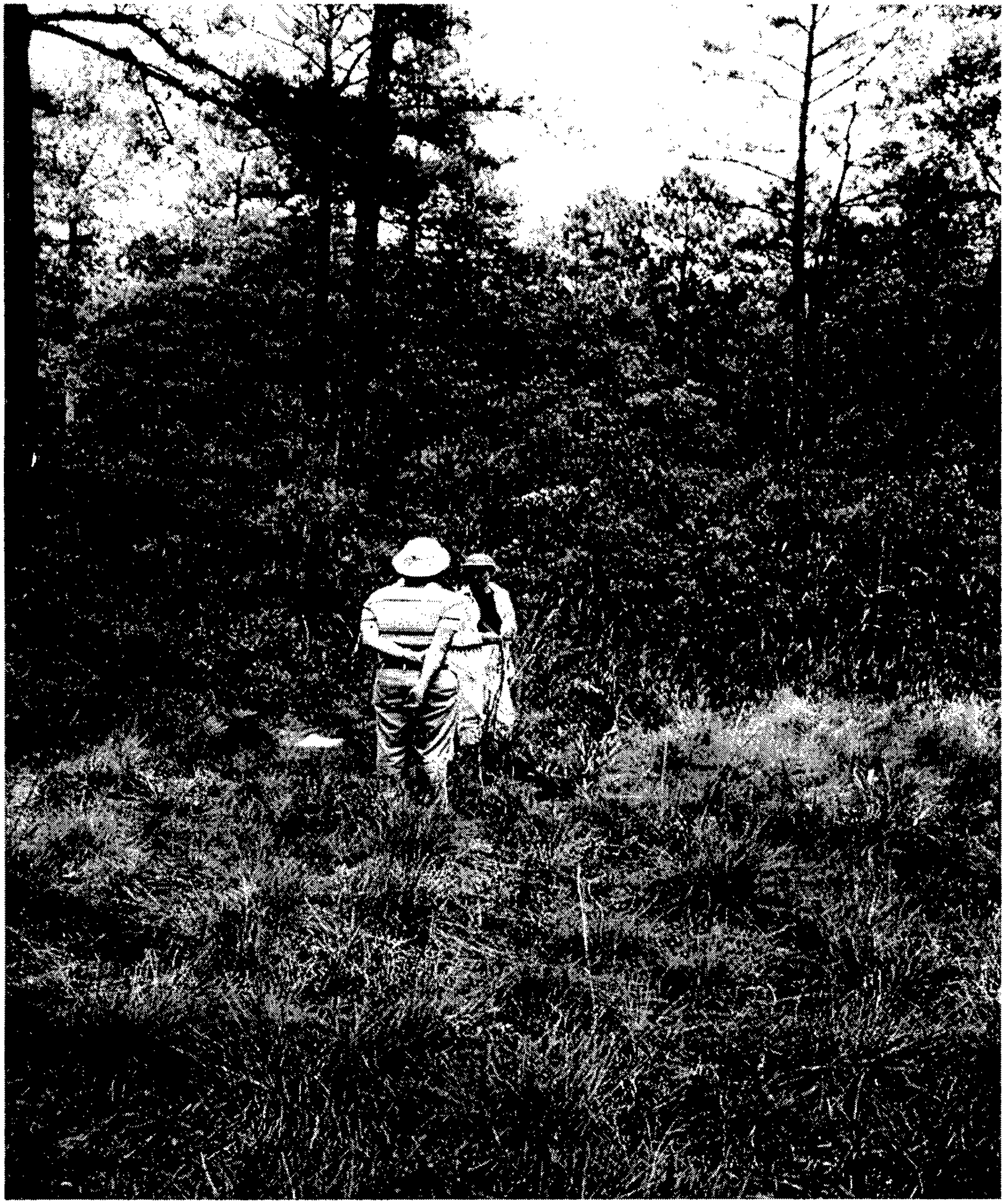

Figure 8. Streamhead Pocosin, showing ecotone with upland longleaf pine community, North Carolina.

Cypress Domes

Cypress domes are distributed throughout Florida and along the Atlantic Coastal Plain and occur in shallow depressions within the pine flatwoods ecosystems (Crownover et al. 1995, Marois and Ewel 1983). Table 1 lists cypress dome communities found on military lands. Cypress domes occur in depressions that are

Figure 9. Streamhead Pocosin and ecotone, North Carolina.

underlaid by drainage impeding clay layers. These depressions contain stagnant water levels with a low pH (3.6 to 4.4; Brown 1981). These communities appear to have a dome shape, from which they are named, because the tallest cypress trees grow in the center of the depression with tree height decreasing towards the edge. The herbaceous and shrub layers may range from very sparse to dense (Brown 1981). Typically shrubs are most dense on mats of organic matter accumulating at the base of cypress trees and are infrequent on the peaty mud in between (Monk and Brown 1965). A herbaceous layer of ferns, forbs, and grasses is typical (Monk and Brown 1965). Fire has occurred in cypress domes historically during the dry season, and is an important factor for maintaining the dominance of cypress in the community and the diverse herbaceous layer near the edge of the community. Periodic surface fires will not alter the vegetational composition of a normally wet dome, but these fires will help to kill newly established slash pines and hardwoods (Cypert 1961, Gunderson 1977, Ewel and Mitsch 1978, Marois and Ewel 1983). The natural fire return interval for this community is not known (Kurz and Wagner 1953).

Most cypress domes are floristically similar. Pond cypress is the dominant canopy tree. Swamp tupelo occurs occasionally and may be the dominant subcanopy tree (Marois and Ewel 1983, Brown 1981). Other tree species sometimes present in the domes are slash pine, swamp red bay, sweet bay (Brown 1981), and sweet gum (Monk and Brown 1965). The major species present in the understory are fetter-bush, wax myrtle, bitter gallberry, Virginia willow, blueberry (*Vaccinium spp.*) (Brown 1981), red maple, loblolly bay (Marois and Ewel 1983), buttonbush (*Cephalanthus occidentalis*), and dahoon (*Ilex cassine*) (Ewel, Davis, and Smith 1989). Virginia chainfern is usually the dominant herb. Other common herbs include lizard's tail (*Saururus cernuus*), red-root (*Lachnanthes tinctoria*), peat moss (Monk and Brown 1965), and Panicum spp. grasses (Brown 1981). Appendix F gives a detailed ecological description of cypress dome communities.

Occurrence on Military Installations

At least 19 DoD installations provided information stating that they have at least one of the six peatland communities covered in this report (Table 1). The following installations provided information that demonstrated they probably do not support peatland communities: Redstone Arsenal, Fort McClellan and Pellham Range, and Anniston Army Depot, AL; NAS Cecil Field, NAS Jacksonville, NAS Orlando, and McCory NTA, FL; Military Corps Logistics Base (MCLB) Albany, Fort Gordon, and Fort Benning, GA; Barksdale Air Force Base, and LAAP, LA; Camp McCain, MS. Other installations in the region did not provide enough information to determine whether or not peatland communities occur on those installations.

3 Biodiversity and TES

Peatland communities are important to regional biodiversity because these communities are sometimes the last extensive natural areas found in the surrounding landscape. Many of these areas were ignored by early settlers because of flooding and poor drainage, until the Timber Act of 1876 declared that swamp lands should be sold to private individuals for agricultural development (Sharitz and Gresham 1998). In the late 1800's and early 1900's, disturbance of these communities increased with new logging techniques, widespread drainage and land conversion to agriculture, forestry plantations, and urban uses. Even sites that escaped direct conversion until today are affected by altered hydrology resulting from extensive drainage across the landscape.

The value of peatland communities often lies in their position or extent at the landscape scale. Basin pocosin communities often comprise the last remaining natural areas among developed land, so they provide important refuge habitat for native plants and animals (Sharitz and Gresham 1998). Since bay forests often develop during long fire return intervals in basin pocosin areas, they support similar species and often serve to connect areas of basin pocosin vegetation. Streamhead pocosins add to landscape biodiversity because of their ecotonal position within watersheds. Pond pine woodlands are important because they are known to provide habitat for the endangered red cockaded woodpecker (RCW, Picoides borealis) as well as offering cover to many other species (Sharitz and Gresham 1998). Cypress domes are generally smaller than pocosins, but provide important amphibian and avian habitat for several endangered species. Remaining white cedar forests are important for regional biodiversity because the community is so uncommon. AWC forests have decreased by over 90 percent in the Carolinas alone (Frost 1987). Specific contributions of these communities to regional biodiversity and endangered species conservation is examined further below.

Basin pocosins are possibly the largest contiguous area of palustrine wetlands, and possibly of undisturbed land, in the southeast (Richardson 1991), although an estimated 69 percent of these communities were lost by 1980 (Richardson 1983). Additional conversion of these communities could reduce regional biodiversity; every effort should be made to conserve existing areas. Low pocosins are more rare than high pocosins or pond pine woodlands. Several rare and endangered species are found in pocosins, including spoonflower (*Peltandra sagittifolia*), northern white beaksedge (*Rhynchospora alba*), tawny cottongrass (*Eriophorum viginicum*), red wolf (*Canis rufus*), black bear (*Ursus americanus*; Schafale and Weakley 1990) and the rough-leaved loosestrife (*Lysimachia asperulaefolia*; Frantz 1995). Pocosin communities are especially important to black bear populations. The black bear was once found throughout the coastal plain, but now relies heavily on pocosin communities for cover (Hellgren, Vaughan, and Stauffer 1991).

Bay forests on DoD lands are know to support two plant species federally listed as "candidates for threatened status": bog spicebush (*Lindera subcoriaceae*) and pondspice (*Litsea aestivalis*; see Table 2). Bay forests also provide habitat for the endangered red wolf and the black bear. Bay forests will grade into other pocosin types, providing important connectivity across the landscape for species that require large home ranges or long-distance dispersal opportunities.

Streamhead pocosins are ecotonal communities, and thus provide many benefits. They function as a buffer to the stream ecosystem, filtering out chemicals, sediment, and nutrients from nearby upland communities. The small, narrow shape of these habitats makes them especially susceptible to degradation due to the management of the surrounding land; fire suppression has been the most damaging impact (Schafale and Weakley 1990). Streamhead pocosins support a high species diversity (due to their ecotonal nature) and thus harbor more rare and endangered plants than the other peatland communities discussed here (Schafale and Weakley 1990). Two federally listed species at risk (SAR): the Carolina asphodel (*Tofieldia glabra*) and Carolina goldenrod (*Solidago pulchra*), and one endangered plant species: the rough-leaved loosestrife, occur in this community on southeast military installations (Table 2). Populations of rough-leaved loosestrife in streamhead pocosin habitat have declined from 19 to 10 populations in recent years (Frantz 1995), warranting close monitoring and aggressive management efforts.

Pond pine woodlands were once widespread throughout the southeast, and are still fairly common in a variety of environments. This community is found under physical conditions similar to a basin pocosin community, and is classified by some as a pocosin type (Weakley and Schafale 1991). Pond pine woodlands are the primary and perhaps the only habitat for the federally endangered RCW among

Table 2. Federally listed threatened, endangered, and SAR occurring in peatland communities on military installations in the southeastern United States.

Common name	Scientific name	Installation	Federal status	Habitat/community (as described in literature)
Woody Plants				
Bog spicebush	*Lindera sub-coriacea*	Eglin AFB, FL Ft. Bragg, NC	SAR	Baygalls (FNAI 1994a), pocosins (Russo et al. 1993), sandy, silty sink hole depressions and swamps (Kral 1983).
Pondspice	*Litsea aestivalis*	Ft. Stewart, GA Camp Lejeune MCB, NC	SAR	Dome swamp (TNC 1995), small depression pocosin (LeBlond, Fussell, and Braswell 1994a), bayheads, edges of sandy sinks, pocosins (Kral 1983, TESII 1994), pond and swamp margins and low wet woodlands (Radford, Ahles, and Bell 1969).
Forbs				
Boykin's Lobelia	*Lobelia boykinii*	Ft. Stewart, GA	SAR	Dome swamp (TNC 1995), swamps, bogs, vernal ponds, wet pine savannas, flatwoods, adjacent ditches, cypress savannas, often in shallow water (Godfrey and Wooten 1981).
Chapman's Butterwort	*Pinguicula planifolia*	Eglin AFB, FL Pensacola NAS, FL	SAR	Dome Swamp (FNAI 1994a, FNAI 1988), bogs, cypress domes, depressions in flatwoods and savannas, often in shallow standing water in moist peat or peat-sand-muck (Kral 1983), peaty ponds, boggy flatwoods, ditches and drainage canals (Godfrey and Wooten 1981).
Carolina Asphodel	*Tofieldia glabra*	Camp Lejeune MCB, NC	SAR	Streamhead Pocosin (LeBlond, Fussell, and Braswell 1994a), savanna and pocosin ecotone (Radford, Ahles, and Bell 1969).
Resinous Boneset	*Eupatorium resinosum*	Ft. Bragg, NC	SAR	Shrub bogs, Pocosins (Russo et al. 1993; Radford, Ahles, and Bell 1969), sphagnous bogs in pinelands (Godfrey and Wooten 1981).

Common name	Scientific name	Installation	Federal status	Habitat/community (as described in literature)
Rough-leaved loosestrife	*Lysimachia asperulaefolia*	Ft. Bragg, NC Ft. Jackson, SC Camp Lejeune Sunny Pt. MCB, NC	E	Streamhead pocosin (Russo et al. 1993), Pocosin (Information sent to authors by B. Pittman 1995), on high hydroperiod, black sandy peats such in seep bog pocosins or boggy flatwoods savanna (Kral 1983), small depression pocosin, pond pine woodland (LeBlond, Fussell, and Braswell 1994a,c), high and low pocosin (Frantz 1995).
Savanna Aster	*Aster chapmanii*	Eglin AFB, FL	SAR	Dome Swamp (FNAI 1994a), bogs, pine savannas and flatwoods, borders of cypress-gum depressions (Godfrey and Wooten 1981).
Grasses, Rushes, Sedges				
Beakrush, Pale	*Rhychospora pallida*	Camp Lejeune MCB, NC	SAR	Small Depression Pocosin (Leblond, Fussell and Braswell 1994c)
Carolina Gold-enrod	*Solidago pulchra*	Camp Lejeune MCB, NC Cherry Point MCAS, NC	SAR	Streamhead Pocosin (LeBlond, Fussell and Braswell 1994a), Pond Pine Wood-land (LeBlond, Fussell and Braswell 1994b,c), moist sandy peat of flatwoods savanna and pocosin borders (Kral 1983).
Curtiss Sandgrass	*Calamovilfa curtissii*	Eglin AFB, FL	SAR	Dome Swamp (FNAI 1994a), moist sands or sandy peats of slash and long-leaf pine-saw palmetto flatwoods and flatwoods savanna (Kral 1983).

these peatland communities (Sharitz and Gresham 1998). Other rare or threatened species include spoonflower, northern white beaksedge, and cranberry in highly disturbed areas or areas that have been recently burned. Species ranked as significantly rare in the state of North Carolina include *Acrapex relicta, Dysgonia similis, Glena pulmosaria, Hemipachnobia subporphyria monochromatea, Lithiacodia n. sp., Macrochilo louisiana, Metarranthis nr. lateritiaria, Orgyia detrita,* and the black bear; the federally endangered red wolf also inhabits pond pine woodlands (North Carolina Natural Heritage Program [NCNHP] and TNC 1995).

AWC forests have become very rare due to widespread draining, logging, fire control, and fragmentation, and have become the target of conservation efforts on that basis. It is estimated that 98 to 99 percent of this community has been destroyed (Noss, LaRoe, and Scott 1992). Nonetheless, this community provides habitat for several state-listed rare species, including *Glena pulmosaria, Hypagyrtis nr. brendae, Metaranthis nr. lateritiaria, Orgyia detrita* (NCNHP and TNC 1995), the red wolf, and the black bear (Fussel et al. 1995).

Cypress domes support five federally listed endangered plants and plant species at risk on southeast military installations (Table 2). Cypress domes are important habitat for many birds, mammals, and amphibians. Two endangered birds, the wood stork (*Mycteria americana*) and bald eagle (*Haliaeetus leucocephalus*) have been known to nest in the pond cypress canopy. Many other upland and water birds also nest in this community (Ewel 1998). The federally endangered flatwoods salamander (Ambystoma cingulatum), striped newt (*Notophthalmus perstriatus*) and gopher frog (*Rana capito capito*) all are found in cypress domes (TNC 1995).

4 Land Use Practices

The vegetation, drainage, and fire regime of remaining peatland communities have been altered by past management practices and other human activities. This section describes the management practices and land uses that peatland communities support on DoD installations in the southeastern United States. These land use practices have the potential to alter the quality of habitat for numerous TES that may depend on remnant communities for survival.

Forestry

In some places, peatlands have been used for forestry on a small scale since the arrival of European settlers. Large-scale logging efforts did not come until later. North Carolina's pocosin areas were railroad-logged of their Atlantic white-cedar and cypress in the late 1800's and early 1900's. Many of these harvested lands were left to regenerate naturally, and were again harvested in the 1950's and 1960's by pulp and paper companies. Forest harvesting operations most likely occur in AWC, pond pine, and cypress dome communities, with limited pulpwood harvesting in bay forest communities (Wharton 1978).

AWC has been used since colonial days for decorative wood products, boat planks, buckets, fencing, and home siding (Ward 1989). As a result of the high demand for its durable nature wood, AWC forests have been repeatedly cut since the time of European settlement, and the extent of this community is greatly diminished (Ash et al. 1983). The decrease in AWC occurrence is not caused by logging alone, but by lack of regeneration due to alterations in fire and hydrologic processes. At one time there were large pure stands of AWC; remaining examples of this community are small and probably do not experience the fire and hydrologic cycles necessary for their long term persistence (D. Stewart, Wildlife Biologist, Alligator River National Wildlife Refuge, professional discussion, 26 March 1996.)

Much original pond pine land has been drained and converted to agriculture or pine plantations (Ash et al. 1983). Pond pine itself is usually harvested as pulpwood due to poor form and slow growth, but on better sites can sometimes be used for sawtimber (Bramlett 1990). Harvesting of pond pine is usually limited by the wet peat soils it occupies (S. Smith, Forester, Dare County Bombing Range, NC, professional discussion, 20 March 1996).

Cypress, like AWC, is prized for the weather-resistant qualities of its heartwood, and is used for mulch, railroad ties, fenceposts, pilings, and chips. Because of the high demand for its wood, almost no old growth cypress remains. Even though much cypress has been allowed to regenerate, the prized heartwood has not had time to develop in the young trees (Ewel, Davis, and Smith 1989). Additionally, over 1 million acres of cypress-dominated communities have been permanently converted to intensive pine plantations and pasture land (Odum and Ewel 1978).

The basin pocosins are not themselves logged, but sometimes they are drained and converted to pine plantations for intensive silviculture (Miller and Maki 1957). Site conversion begins with the digging of a drainage ditch to remove surface water and make the site dry enough to support logging machinery. Often, ditch spoil is piled beside the new drainage ditch and used for road material. After 1 or 2 years of drainage, the original vegetation is logged. Unmerchantable trees and understory vegetation are pushed down with bulldozers, crushed with large bladed drums, and burned. The soil is mounded into beds, into which phosphorus fertilizer is often mixed, and pine seedlings are then planted (Sharitz and Gresham 1998).

Clearcutting combined with artificial regeneration has been the most widely practiced method of harvest by the forest industry in the lower Atlantic Coastal Plain. Artificial regeneration is usually done with loblolly or slash pine (Ash et al. 1983) but may be done with the original species in the case of AWC (S. Smith, 20 March 1996). Clearcutting is suited to cultivation of fast-growing species that are intolerant of competition from other trees. Logging can be done by track or, more commonly, by rubber-tired skidders (Ash et al. 1983). Skidding with rubber-tired tractors is less expensive than with crawler-type tractors, but increases the potential for erosion and soil compaction (Dyrness 1972).

Agriculture

Converting peatlands for row-crop agriculture, like timber harvesting, has occurred since the late 1700's. Much like converting land to pine plantations, conversion to agriculture involved draining and clearing of timber and other vegetation. Proper drainage is attained through a series of canals that, when completed, also act as a means of transport for agricultural and forestry products (Lilly 1981). When drained, these soils are productive for crops such as rice, corn, soybeans and cotton.

During and after the Civil War there was economic depression in much of the south, and funds were not available drain more land. From this period until the early 1900s, the main land use of peatland communities was the harvesting of timber (Lilly 1981). In the early 1900's there was renewed interest in converting peatlands to agriculture. In 1909, the state of North Carolina established drainage districts, and by 1911, over 280,000 ha (700,000 acres) had been enrolled in these districts. As some of these districts failed, the land was sold back to the government, which created state and national forests, such as the Hoffmann Forest and the Croatan National Forest in North Carolina (Sharitz and Gresham 1998).

In the 1950's, the Agricultural Conservation Program (ACP) of the Soil Conservation Service provided federal cost sharing for improved drainage of cropland, which led to more wetland drainage. Today, clearing wetlands for agriculture is no longer practiced. The 1985 and 1990 Farm Bills prohibit destruction of wetlands if the landowner wishes to remain eligible for USDA farm subsidies (Sharitz and Gresham 1998).

Fire

Before and during the early part of European settlement, fire was a natural part of the peatland landscape. In some instances, fire return intervals increased; in other areas, fire return intervals decreased due to human alterations of the landscape. Basin pocosins were less dense in their natural state than they are today, due to recent reduction or elimination of fire. Before the extensive isolation of pocosins by canals (Figure 10) and the suppression of fire, pocosins were estimated to burn once every 13 to 50 years (low pocosins), or once every 25 to 50 years (high pocosin) (Sharitz and Gresham 1998). Although uncommon today, this fire regime is characteristic of high quality pocosins (T. Cruise, Alligator River National Wildlife Refuge, professional discussion, 18 April 1996).

In areas where the vegetation was valued for timber, drainage increased and wildfires became more common and more intense due to the drier state of the fuel

Figure 10. Canal dissecting low pocosin in North Caolina.

load (Sharitz and Gresham 1998). As these areas were considered more valuable, landowners and government agencies undertook wildfire control programs, and reduced the frequency and extent of fires. The current practice of intense ditching of peatland areas allows for rapid access to peatlands for wildfire control (Sharitz and Gresham 1998).

Since wildfires historically have played a pivotal role in regeneration of AWC forests, managers attempt controlled burns to manage this community. These controlled burns do not always function as an adequate replacement for the stand-killing crown fires that historically preceded (and facilitated) AWC regeneration. Controlled burns must be conducted when conditions are favorable for controlling the fire and this may not provide adequate clearing of the vegetation (Motzkin, Patterson, and Drake 1993). This issue illustrates the difficulty of managing small patches of plant communities that historically were maintained through large-scale fire.

5 Community Quality

The Use of a Community Quality Assessment

To practice sound ecosystem management, several policy goals must be reconciled: the military mission, protection of TES, and consumptive land uses such as production of forest commodities. Decisions regarding land use priorities can be guided by site classification on the basis of ecological quality. Site quality initially can be assigned using baseline data, but should be augmented by a monitoring program that evaluates the effects of land use decisions. Determination of community quality has obvious benefits for TES conservation planning. Low quality communities do not provide the same habitat quality for TES as higher quality communities, and therefore should be treated differently in terms of protection, restoration efforts, and allowable land uses. Use of a quality ranking system for management purposes can assure that protection priority is given to highest quality TES habitat. Furthermore, use of this system can assure that restoration activities are used for communities that have the potential to become high quality TES habitat with minimum restoration efforts. Similarly, use of a quality ranking system can ensure that efforts are not wasted in the restoration of low quality communities. Finally, plant communities on installations are subject to multiple land uses, and use of a quality ranking system in combination with an assessment of impacts of various land uses can allow managers to determine which activities are appropriate in which communities, based on the potential to provide quality habitat for TES. The ranking system developed for Eglin AFB, FL, using "Type" categories to denote ecological quality, was introduced in the companion document by Harper et al. (1997) and has been adapted for this report as well (more information can be found in Appendix G). Management recommendations found in this document are oriented towards the highest quality sites on military installations, unless specifically noted otherwise.

Indicators of Community Quality

Bay Forests

Type I. Areas dominated by loblolly bay, sweet bay, and red bay, with a dense understory of shrubs and vines. Older stands will have developed a more uneven age class in the canopy, and will have multiple vegetation layers present. Stands over 50 years old might be considered old growth and high quality. Hydrology will be relatively unaltered, although seasonal water table fluctuations may be present. Close proximity to other high quality areas increase the value of this community for TES conservation.

Type II. Stand may be younger, with more uniform structure due to fire or other disturbance, but species composition should be similar to Type I. These areas may have a lower water table due to adjacent or nearby ditches or canals. These areas could be improved by restoring natural hydrology to the area.

Type III. Area may retain some soil characteristics of bay forests, but most of the vegetation has been removed and area has been converted.

Type IV. These areas have been converted to other land uses, and lack the soil qualities that support the original bay forest vegetation type. These areas may have undergone severe fire (or other disturbance) that has removed much of the upper organic layer of the soil, making it unlikely that bay forest would inhabit the site, even if natural hydrology was restored.

Atlantic White Cedar Forests

Type I. Stands of AWC are even-aged, dense, and almost 100 percent AWC dominance in the canopy. Because this community is adapted to catastrophic fire and naturally occurred in even-aged stands, young even-aged stands are not regarded negatively as they are for many other forest types. Microtopography in this community consists of hollows and mounds of approximately 1 meter heights and depths. The mounds are formed from the accumulation of organic matter and the growth of sphagnum moss on root systems and debris (Ehrenfeld 1995). Quality examples of AWC forests are interpreted partly by the surrounding landscape. Young stands that occur within communities that are exemplary, such as high pocosins and non-alluvial swamps, are considered to be higher quality (Fussel et al. 1995).

Type II. The canopy is composed of at least 50 percent AWC (Fussel et al. 1995). These areas are presumed to have once been more strongly dominated by cedar; they may occur in locations on the landscape where they would not naturally be expected due to changes in physical characteristics of the site or artificial reseeding. The soil may be somewhat disturbed by rutting and there may be changes in the natural microtopography from past logging activities (Fussel et al. 1995).

Type III. Recently clear-cut areas that are not now dominated by white cedar but, based on presence of stumps, clearly were prior to cutting (Fussel et al. 1995).

Type IV. These areas are completely converted to other community types for alternate land uses, such as pine planting and agriculture.

Basin Pocosins

Type I. High quality examples of low and high pocosins have an absence of artificial disturbance except for limited local disturbances, such as bombardier trails. They do not include sites where plantations have been created. Type I sites must be large and contiguous with little fragmentation and ditching-related impacts to hydrology (Fussel et al. 1995). Low pocosins are characterized by shrub vegetation reaching less than 1.5 meters high; high pocosins grow to 1.5 to 3 meters in height, which is intermediate between low pocosin and pond pine woodland. Trees in both communities consist mostly of pond pine that is scattered and relatively low in stature, with those in low pocosins being more stunted. Small depression pocosins may be similar to either except that they do not cover large areas (Fussel et al. 1995).

Type II. These include pocosin areas that have been subdivided by canals and thereby have undergone changes in hydrology and/or fire regime. Many areas that are high pocosins today were low pocosins before lowering of the water level and suppressing fire (T. Cruise, 18 April 1996); such communities may be restored by reverting these natural processes to past levels.

Type III. These include pocosins that have been converted but may have retained certain soil characteristics, such as an adequate peat layer, and can be restored if the proper physical characteristics of the community were restored and seed sources were available (Fussel et al. 1995).

Type IV. These areas have been converted and eroded such that they would not support the original community type even under restoration of original hydrologic and fire regimes.

Pond Pine Woodland

Type I. Quality examples have a substantial pond pine canopy. The shrub layer is generally taller than that found in high pocosins. Pond pine woodland that has experienced severe fire may appear very similar to high pocosin, although it can often be distinguished by the presence of remaining live and dead pond pines in high abundance (Fussel et al. 1995). Natural habitats are believed to have had a fire frequency of 3 to 5 years (Wells 1942, Hughes 1966). A dense understory of cane, which indicates that fire occurred within the past 15 years, is characteristic of the original habitat in most areas and is considered an indicator of high quality (Hughes 1966, Fussel et al. 1995). High quality stands have a mosaic of canopy ages. Because of the slow growth of trees in this ecosystem, old stands are considered particularly significant (Fussel et al. 1995).

Type II. Stands may be young and relatively even aged due to past logging, but are still dominated by pond pine in the canopy layer. In the absence of its natural fire regime, this community is likely to develop a subcanopy of species such as red maple, loblolly bay, and swamp red bay. The area may be rutted or dissected with skid trails from past logging. Switch cane is absent and the understory may be dense with shrubs due to fire suppression (Fussel et al. 1995).

Type III. These areas have recently been cut over as evidenced by the presence of stumps, and they may or may not return naturally due to changes in the natural hydrology and/or fire regime. Also included are areas that supported pond pine in the past, but no longer can, due to lack of regeneration after cutting or changes in the natural hydrology and/or fire regime (Fussel et al. 1995).

Type IV. These areas have been converted for alternate land use, including artificial seeding of other pine species for harvest, or for row crop agriculture.

Streamhead pocosins

Type I. High quality examples of this community type have intact seepage from the upland habitat, without disturbances to the soil that alter the semi-permanent saturated condition (Schafale and Weakley 1990). The characteristics and quality of the upslope habitats adjacent to the community are important factors affecting the quality of this community type. Upslope areas should be free of logging or other activities that might affect the community through siltation or chemical pollution. High quality sites experience fire every 1 to 5 years, with decreasing burn frequencies along the moisture gradient into the center of the community. Streamhead pocosins have a scattered canopy, and, although their shrub layer is dense, it is less so than that of other pocosin types; the community has a well-developed herbaceous layer (Martin 1992, Schafale and Weakley 1990).

Type II. These streamhead pocosins may have suffered soil disturbance, such as rutting from vehicles, ditching, or installment of fire breaks, that have altered their hydrology. They may have greater concentrations of trees and shrubs indicating less frequent fire than those under the natural fire regime. Some siltation may have occurred due to soil disturbance on the upslope (Martin 1992).

Type III. These areas are overgrown with shrubs or a closed canopy, resulting in a less vigorous herbaceous layer with lower cover and species diversity. Heavy siltation from adjacent upland activities may be responsible for impacts to the herbaceous layer. The hydrology may be seriously altered due to changes in the water source or stream flow, or from drainage ditches or ruts caused by heavy vehicle traffic. As a result, the community does not provide its natural seepage function (Martin 1992).

Type IV. These areas have been converted for other land uses and the soil is permanently altered or eroded.

Cypress Domes

Type I. High quality cypress domes should display distinct, concentric zones of vegetation along a hydrologic gradient. Species abundance and diversity are typically low in the deeper, central portion of the community, and increase outwardly toward the shallow and drier edges of the depression. At least some standing water is present during the wet season, while the surface of the soil becomes exposed during the dry season (TNC 1995). A diverse, grass-dominated ecotone, in which most rare plants of this habitat are found (Godfrey and Wooten 1981, Kral 1983, Johnson 1993), generally occurs between the water margin and the surrounding flatwoods (Florida Natural Areas Inventory [FNAI] 1994a). Indigenous salamanders are present in cypress domes with open understories and herbaceous plants (TNC 1995). Emergent herbaceous species surround the wettest part of the depression and are important for amphibians that need herbaceous vegetation for egg deposition and shelter for their larva that feed within the clumps of vegetation (FNAI 1994a). The tree canopy and subcanopy are moderately open and consist of pond cypress, slash pine, and black gum; they usually have a characteristic dome shape with larger trees in the center and smaller trees toward the edge. Shrubs are sparse in the ecotone and dense in the basin, and consist of myrtle-leaved holly, St. John's wort (Hypericum spp.), and fetter-bush (FNAI 1994a).

Herbs and small shrubs are sparse in the center of the dome, but typically a very dense herb-dominated ecotone exists around the periphery. Leaf litter and peat are typically sparse and thin, and little evidence of anthropogenic disturbances to the soil, hydrology, or vegetation exists.

These high quality communities should have little evidence of tree stumps, fire breaks, drainage ditches, trash, or hog damage. Evidence of turpentine extraction may be apparent on older slash pines without diminishing the quality of the community. Weedy and exotic species are rare or absent (FNAI 1994a). Important field indicators include the characteristic "dome shape" of the woody vegetation, lack of weedy and exotic species, and lack of physical disturbance to the soil, hydrology, and vegetation (FNAI 1994a).

Type II. Vegetation composition and structure is similar to that of Type I described above, except that Type II dome swamps may have experienced anthropogenic disturbances. Weedy and exotic species may be present, and the tree canopy may lack the characteristic dome shape of the Type I dome swamps. Old "flat top" cypress are either sparse or absent. Shrubs may be dense, reducing or almost eliminating the herbaceous layer, and there may be a thick leaf or peat layer due to long-term fire suppression (FNAI 1994a).

There is often evidence of physical disturbance to the soil and vegetation, such as tree stumps, fire breaks, drainage ditches, trash, and feral hog damage. Some species typically found in dome swamps in relatively low abundances may exhibit weedy behavior following physical disturbance or fire suppression. These include titi, sweet gallberry, and blaspheme vine (FNAI 1994a).

Type III. In addition to the characteristics of the Type II habitat, trees in these areas may have been cut. However, the understory displays enough elements of the original habitat to be readily recognized. Slash pine and/or gum may have largely replaced the cypress. The hydrology may have been completely altered. The area may have been highly disturbed by logging activity or grazing (FNAI 1994a).

Type IV. This habitat shows little more than its original topography. It may have been drained and converted to row crops, pine plantations, or pasture with a few cypress trees left for shade (FNAI 1994a).

6 Impacts and Management

Forestry Activities

Impacts

Timber harvesting for pulp or lumber occurs on DoD's forested peatlands in the southeast. Activities related to forestry may affect the soils, hydrology, and vegetation of these communities. Modified rubber-tired carriers with wide or dual tires increase mobility, but can cause a large amount of visible damage to the site (Jackson and Stokes 1991). Dual tire skidders are cost effective under wet conditions and are able to work in harsh conditions, but also may leave the site with high levels of disturbance. The capabilities of dual tire skidders might allow loggers to work beyond acceptable ground condition limits (Jackson and Stokes 1991). The resulting soil damage under wet conditions can permanently reduce tree growth on the site (Terry and Campbell 1981). Logging in bay forests that occur on seepage slopes is known to destroy the soil structure of the community (FNAI 1994a). Disrupted soil can become stabilized if vegetation regrowth is successful within a few years following tree harvest (Campbell and Hughes 1991).

The removal of vegetation and alteration of soils with high organic matter content can result in substantial short-term changes in the timing, duration, and discharge rates of flood waters (Ash et al. 1983). Immediately after harvesting there may be temporary increases of fresh water delivery, sediment erosion, and nutrient and chemical loading in runoff waters (Skaggs et al. 1980, Ash et al. 1983). High-flow flushing in rivers due to storm events could transport sediment down channel, where some may enter into small creeks with relatively sensitive spawning beds and nursery areas. The light reduction that results from siltation can have serious effects on aquatic organisms and habitat (Corbett, Lynch and Sopper 1978). Clearing of vegetation near waterways may significantly increase the temperature of surface runoff, adversely affecting aquatic organisms.

Roads running through peatlands may pose a threat to these communities. They function as berms that restrict natural water movement (Miller and Maki 1957, Gosselink et al. 1990) and they expose soil, allowing for increased erosion (Gosselink et al. 1990, Walbridge and Lockaby 1994, FNAI 1994a). Extensive systems of roads and canals were constructed in the 1980's specifically to increase logging access in Dare County, NC (Laney and Noffsinger 1987).

Nutrients in runoff can increase through fertilization and/or from the release of soil nutrients during soil disturbance. Organic soils contribute large amounts of nutrients to runoff, whether or not they are fertilized, if they are ditched and drained (Hortenstine and Forbes 1972). Erosion of peatlands also results in considerable nutrient export (Crisp 1966). Nitrogen concentration in runoff is much higher in developed areas (pine plantings, etc.), and is highest from mineral soils (Ash et al. 1983). Conversely, phosphorus concentration in runoff is higher in cleared peatlands, and is greatest in deep peat areas (Ash et al. 1983).

Timber harvest directly affects the composition of the peatland plant community. Some species and communities, even though they are adapted to natural disturbance, may not regenerate themselves following logging. Logging and its consequential alteration of hydrology is listed as one of the two processes responsible for the more than 90 percent decrease in white cedar acreage (Frost 1987). AWC often do not regenerate and are replaced by pocosin (Ash et al. 1983, D. Stewart 1996, McKinley and Day 1979) or swamp hardwoods (Frost 1987, Zampella 1987). Shrub-dominated vegetation has been documented as replacing logged AWC stands in the Dismal Swamp (McKinley and Day 1979) and Dare County Air Force Range (Fussel et al. 1995); red maple and black gum have replaced white cedar following logging in the Dismal Swamp (Levy 1987). The rapid growth of hardwood sprouts enables them to gain an initial advantage over the white cedar reproduction that starts from seed. Rapid growth may be the primary reason for the frequent replacement of AWC with hardwoods following cutting (Little 1950). Seedlings may become established under cover of shrubs following logging, but the shrubs rapidly become thick and exclude light, making establishment of the cedar very difficult (Korstian and Brush 1931, Akerman 1923). Conversion of AWC stands to hardwoods following cutting is increased by leaving many of the larger hardwoods (Little 1950, Frost 1987). Over time, the conversion of white cedar stands may proceed at an increasing rate as more hardwoods reach the overstory and are again left after logging (Little 1950, Frost 1987). This process seems to be influenced in part by the advanced reproduction of hardwoods present before logging and the relative growth rate of the species present (Little 1950).

Slash and brush that remain following cedar harvest also affect the regeneration of AWC. Piles of slash, and surviving shrubs, shade out young AWC seedlings and provide fuel for wild fires, encouraging the establishment of more fire-tolerant pocosin species to the exclusion of AWC (Ash et al. 1983). White cedar seedlings have been observed to form dense stands in cleared areas between masses of slash, while few seeds germinated and still fewer survived under the dense slash (Korstian 1924). Areas that are relatively free of logging debris have been observed to have 30 to 40 times as many seedlings as areas with debris. In slash-free areas, the largest seedlings were two to four times taller than those found in slash-covered areas (Little 1950). Hardwood sprouts are able to emerge through dense slash, however, and by the time slash has decayed sufficiently to form a seedbed suitable for white cedar, the hardwoods have become so tall that they form the main part of the stand. Logging slash, therefore, results in regeneration of mixed stands (Korstian and Brush 1931).

AWC do not become established in the hollows of the naturally hummocky microtopography of the forest floor (Figure 11), only on the elevated mounds formed from roots and debris (Akerman 1923, Ehrenfeld 1995). Akerman (1923) observed that only the moss-covered logs, stumps, or hummocks that are above the water level form favorable seedbeds during periods of high water in the spring and early summer. Logging operations may reduce the elevation of these mounds. Logs laid down to create skid trails (Figure 12) sink over time (Figure 13) and cause depressions in the soil that last for several years. These depressions fill with water making them unsuitable for reestablishment by cedar (D. Stewart, 26 March 1996). Logging may also reduce the natural cover of sphagnum moss characteristic of this habitat; Ehrenfeld and Schneider (1991) stated that sphagnum moss is sensitive to trampling (Studlar 1983), changes in the hydrological regime (Andrus, Wagner, and Titus 1983), and elevated nitrogen concentrations caused by fertilization (Press, Woodin, and Lee 1986). The decline in cedar establishment following logging may be related to the decline of sphagnum moss following disturbance (Ehrenfeld and Schneider 1991). Sphagnum moss is the substrate on which cedar reproduction is generally found (Little 1950) and it holds a large reservoir of buried viable seed (Korstian 1924, Little 1950). Changes in Sphagnum spp. cover may have important implications regarding successional change and community dynamics (Ehrenfeld and Schneider 1991).

Figure 11. Hummocky microtopography of the Atlantic White Cedar forest floor.

Figure 12. Skid trail built with downed logs on wet peat soils in North Carolina.

Figure 13. Older skid trail with sinking logs, North Carolina.

Despite the many cases in which AWC has not regenerated following logging, it has been suggested that clearcutting helps maintain this community type by mimicking the stand-killing fires of the past (S. Smith, 20 March 1996; Little 1950). Apparently, the success of regeneration depends on site-specific conditions and timing of disturbance following timber harvest (Figure 14; Little 1950). Whether or not fire is beneficial for white cedar regeneration following clearcutting depends on several variables. These include: hardwood composition and abundance in the original stand, numbers of viable seed stored in the forest floor at varying depths, the composition of nearby stands that survive the fire and will disperse seed over the burn, the depth to which the fire burns into the forest floor, and the position of the water table after the burn (Little 1950). Further study is needed to better understand the factors involved in successful AWC regeneration.

Repeated cutting of AWC forests has created younger stands that are more susceptible to damage; in addition, repeated removal of the competing overstory has encouraged shrubby understories. Such understories would be absent under a natural closed AWC canopy, particularly if affected by periodic, light fires; when understories do exist, they tend to increase the intensity of any fire (Little 1950).

Cypress dome communities are also affected by timber harvests. Changes in harvesting equipment and marketing have made the clearcutting method of regeneration a much more common management practice. Now small and large trees are just as likely to be cut. Additionally, modern equipment allows deeper penetration into wetlands (Ewel, Davis, and Smith 1989). Although cypress trees can reproduce vegetatively from stumps and produce cones within 2 years, logging in cypress wetlands has been reported to result in poor cypress regeneration and changes in species composition (Bull 1949, Allen 1962, Gunderson 1977). Drainage of cypress domes to improve access for timber harvest often favors hardwood regeneration at the expense of cypress (Marois and Ewel 1983). In some cases, though, cypress reproduction has responded favorably to clearcutting, presumably due to the increased light conditions (Marois and Ewel 1983). Ewel, Davis, and Smith (1989) concluded that clearcutting without immediate burning, and with no alteration of the hydrology, has little long-term effect on ecological and hydrological patterns on the community and surrounding areas. Because of the importance of cypress domes to wildlife and endangered species, however, the practice of clearcutting has undergone scrutiny (Ewel, Davis, and Smith 1989) and is not presently practiced on military installations (Laurie Gaywin, The Nature Conservancy, Savanna, GA, professional discussion, 15 May 1996).

Pond pine woodlands is another community sometimes used for logging. Pond pine woodlands in North Carolina that were cut and not reseeded, and were protected from fire, contain almost no pond pine. This suggests that logging is not an adequate substitute for fire to promote the regeneration of this species (Fussel et al. 1995). Pond pine is harvested mostly as pulpwood, since it lacks the straight boles of other pines, like loblolly and slash pine (S. Smith, 20 March 1996). Harvesting for pulpwood is disadvantageous compared to harvesting boles of trees and leaving leaves and branches since it results in a considerably larger export of nutrients from the ecosystem (E. DeLucia, Professor, Department of Plant Biology, University of Illinois, professional discussion, 17 March 1996). Often, pulpwood harvest of pond pine is conducted after draining the area and is followed by reseeding with slash or loblolly pine (Ash et al. 1983).

Management Recommendations

Management of peatland forested communities in sites and watersheds where TES conservation is a primary concern should seek to minimize soil disturbances and erosion-related impacts to waterways, and should promote the native species, structural characteristics, and disturbance processes that enhance TES survival and reproduction. Although the relationship between peatland habitat requirements of TES species and human activities largely has not been documented, recommendations here are based on review of known conservation literature.

Intensive management for maximum wood production should not be practiced near ditches, streams, or other bodies of water. Buffer strips between areas of erosion and watercourses should be maintained permanently, and their effectiveness should be monitored. Within buffer strips, only selective harvesting should be practiced, and use of heavy equipment, prescribed burning, and application of fertilizers and pesticides should be avoided. To protect waterways from aerial, ground vehicle, hand spraying, and hand injection methods of pesticide application, untreated buffer strips of 30, 15, 7.5, and 4.5 meters, respectively, are recommended (Ash et al. 1983). Pesticide use in forests is best limited to precise applications in specific areas, avoiding widespread aerial application (Ash et al. 1983). When it is judged necessary to use pesticide and/or fertilizer on peatlands, it is best to avoid application during times of high rainfall and runoff, to prevent pollution of surrounding community types (Ash et al. 1983).

Clearcut sizes should be minimized, ideally including no more than 5 acres, with buffer strips between cuts. Implementing smaller individual clearcuts helps to prevent erosion and runoff immediately following clearcutting (Ash et al. 1983) and reduces impacts to wildlife (D. Stewart, 26 March 1996).

Roads that are not used for logging, military, or recreational needs should be closed and managed for erosion problems (FNAI 1994a). After harvest, roads should be closed, seeded with vegetation, and barricaded if possible. In forested peatlands, forest buffer strips of 30 m should be maintained between roads and streams or ditches. In shrub-dominated pocosins, where the road must be built next to a canal, an interception ditch filled with vegetation should be created between the road and canal (Ash et al. 1983).

Several alternatives exist for low-impact harvesting systems on wet soils. The following suggestions are taken from Jackson and Stokes (1991).

Felling: Mechanized felling can be accomplished using swing feller-bunchers on tracks. Although costly, this equipment reduces disturbance by limiting the amount of travel on the site and by using wide tracks. Under certain circumstances, mats may be desired to increase feller-buncher mobility and reduce site disturbance. Felling technology is now available that includes lightweight, long-reaching machines that combine high production with little disturbance. Use of grapple-saws would increase the flexibility of the feller-buncher since the weight on the end of the boom would be reduced and bucking and topping problems should be minimized.

Such a machine can cut the trees, remove the tops and some of the larger limbs, buck logs, and pile stems. Integrating all of these functions into one machine can reduce subsequent extraction impacts.

Extraction: Vehicles with wide tires or tracks are recommended since they reduce rutting of the soil and the resulting hydrologic impacts. Fifty and 68-inch-wide tires have been used in the southern United States. Such tires may exert pressure as low as 3 psi, and are still relatively maneuverable. Mellgren and Heidersdorf (1984) list the advantages of extra-wide tires, including: increased productivity, fuel savings, reduction in ground disturbance, less soil compaction, smaller machine requirements, smoother ride, improved stability, and increased access to timber. Disadvantages were listed as high price, reduced maneuverability, and necessity for specialized repair and maintenance equipment.

Flexible tracked skidders have been reintroduced; design changes decreased operating costs to the point that such machines may be cost effective. Advantages of track skidding over tire skidding include lower ground pressure and higher traction. These have been observed to have lower overall soil impacts in peat soils (D. Stewart, 26 March 1996).

Large, six-wheel drive, wide-tire forwarders in combination with grapple skidder, feller-bunchers, and in-woods loaders can significantly reduce the number of logging roads needed; they may also make logging feasible where conventional systems cannot operate. Such equipment allows access to roadless areas in such a way that also improves stability, safety, and comfort, requires less maintenance, and provides greater productivity, because the machine stays on top of even saturated ground, which also reduces residual damage to the site (Griffin 1989). Large payloads reduce the number of passes required on the same trail. The clambunk skidder has been used successfully in the marsh lands of Canada. It has a loaded psi of 4.8 with 68-inch tires and 7.4 with 44-inch-wide tires. Generally the productivity of one large capacity forwarder or clambunk skidder is equivalent to three regular skidders. It is easy to imagine how such equipment may reduce the damaging effects that logging can have on peatland forests (Jackson and Stokes 1991). Quantitative research is needed at this time to determine whether the benefits this equipment offers is adequate to allow intensive forestry operations to coexist with TES habitat on peatland soils in the long run.

Transport: Since building roads is more disturbing to the site than harvesting, and since roads are expensive to build and maintain, options that allow log removal on lower quality roads or transport of wood further without roads are advantageous. Central tire inflation (CTI) systems that allow the use of low-pressure tires on logging trucks can permit the trucks to operate on low quality roads and reduce road maintenance. Special matting and matting-handling equipment may allow the use of low-quality roads and reduce residual disturbance (Jackson and Stokes 1991).

In addition to these general management recommendations, the different peatland communities discussed in this report may have specific requirements. Bay forests that serve as TES habitat and occur on seepage slopes should not be harvested, since the machinery involved would be likely to permanently alter the soil structure and hydrology required to maintain this community (Wharton 1978).

Basin pocosins are affected indirectly by logging or road construction in adjacent areas. Forestry practices throughout watersheds that supply water and nutrients to pocosin wetlands should minimize changes in hydrologic input, nutrient and chemical input, and siltation from uplands, if management objectives include conservation of TES that rely on the basin pocosin community for habitat (Ash et al. 1983).

Although harvest of cypress domes is not reported to occur currently on DoD lands, nearby logging of adjacent areas may lead to impacts. When nearby logging occurs, adequate buffer zones should be maintained between the cypress dome and logging activities. Buffer zone recommendations range from 30 to 50 meters for other plant communities with similar drainage characteristics (i.e., herbaceous seeps in the Southeast; Platt et al. 1990; Palis and Jensen 1995). Because there is little quantitative data to guide buffer zone design in peatland communities, managers should closely monitor areas potentially affected to determine if a larger buffer zone might be needed (Harper et al. 1997). Maintaining adequate buffer zones will avoid direct disturbance of rare plants in the ecotone, decrease siltation, and prevent the addition of chemicals into cypress domes during precipitation events.

AWC forests are a rare community that has adapted to an identifiable disturbance regime that has largely changed; remnant examples of these forests should receive high priority for conservation and old growth characteristics. Across an entire landscape, many separate high quality sites should be maintained to increase species diversity and improve survival probability in the face of catastrophic fire, disease, or storm damage.

Conservation of different successional stages is also desirable across the landscape, so if one patch of AWC is destroyed, sufficient similar patches persist. Although the oldest stands are most attractive for harvesting, some climax communities should be protected since these rare mature stands require many years (200 to 300) for their development (Ash et al. 1983). Old growth forests are particularly valuable for both species richness and abundance of wildlife (Carter 1987).

If logging of an AWC is determined to be desirable, and the site does not serve as TES habitat, the following practices may increase the probability that a high quality stand of AWC may regenerate:

1. Cut all trees in an area, including all hardwoods. Cutting all hardwoods in areas logged for AWC will promote pure AWC stands, since advanced recruitment of hardwoods results in mixed stands at best. Furthermore, removal of competitive species may be required during early years of the stand development (Little 1950).
2. Cut 5 acres or fewer at one time, leaving a thick band or dense patches of mature AWC on the western edge of the harvest site, to serve as seed sources. Distance and direction from a seed source greatly affect the establishment of white cedar seedlings. Because of the prevailing westerly winds in most areas where this habitat occurs, white cedar reproduction extends rather slowly westward where seed dispersal from tall trees is as little as 20 m. The establishment of white cedar is favored on the eastern side of seed sources. It is advisable to leave at least some large trees on the western edge of a small clearcut to provide seed in case the seed source in the soil is not sufficient for regeneration, or the first cohort of regenerating cedar fail to survive (Little 1950). Cutting in strips, checkerboard patterns, or small areas within larger AWC forest has been reported to facilitate satisfactory reseeding from the remaining individuals (Cottrell 1929, Noyes 1939, Little 1950), and is consistent with management goals to preserve older stands for wildlife. Strips with widths of 30 to 50 m have been recommended (Moore 1946), depending on the heights of the surrounding trees (Little 1950). Older trees produce more seed of higher genetic value (Little 1950). Leaving small stands is more advisable than leaving isolated trees because of the risk of windthrow (Little 1950, Moore and Carter 1987).
3. Create and use minimal roads into the stand, and the fewest number of passes possible.
4. Clear all brush and slash piles. Following the harvest and during a period with a high water table, conduct a light prescribed burn on the site to totally eliminate slash.
5. Control hardwood competition during early stand formation. This is important since the tree species that are present in the early stages of succession tend to remain or increase in the stand over harvest cycles (S. Smith, 20 March 1996).

Fire Management

Impacts

Fire is the dominant natural disturbance in the southeastern United States; many plant communities in the region are adapted to this disturbance and even depend on fire for persistence. However, one community discussed here (bay forests) is destroyed by fire, and the other communities are adapted to certain intensities and frequencies of fire. A fire regime characterized by more frequent, less frequent, or more intense fires will serve as a negative impact to most of these communities. Some of the decline in these communities is due to almost complete fire suppression, which may result in loss of habitat for endangered species (Sutter and Kral 1994).

The bay forest community is considered a late-successional community that is destroyed by fire. Bay forests usually revert to a grass-sedge community, basin or streamhead pocosin, or AWC forest after burning occurs (Penfound 1952). In areas where bay forests serve as valued wildlife or TES habitat, fire should be considered detrimental.

Unlike bay forest communities, AWC communities depend on periodic fire to create conditions for successful regeneration (Motzkin, Patterson, and Drake 1993). It is thought that fire return intervals of 25 to 250 are appropriate for maintenance of AWC forests (Frost 1987).

It has been known since at least 1924 (Korstian 1924) that AWC regenerates following a fire during a period of high water table. Under moist conditions, fire does not burn the top layer of peat in which there may be stored enormous numbers of viable seeds. With fire control and fragmentation of large peatlands, suitable fires have become extremely rare. The loss of natural regeneration, coupled with widespread logging and draining, have restricted these once-abundant communities to rare sites throughout their range (Fussel et al. 1995).

Despite the requirement for occasional catastrophic fire for community persistence, frequent fire is harmful to the AWC communities under certain conditions. Intense fire kills the adult trees, with regeneration coming from a seed bank in the peat. However, many hardwood competitors can sprout from roots if the fire is of moderate intensity. For this reason, certain fire regimes are detrimental to high quality AWC forests. Younger stands are more susceptible to fire damage than older ones (Little 1950). Little (1950) stated that the effect of fires on the white cedar community had not been as positive as concluded by Buell and Cain (1943), and that fire and cutting have usually worked together to reduce the proportion of white cedar compared to other associated species. Severe fires, when the soil is dry, destroy the upper layer of peat and the cedar seed bank (Buell and Cain 1943).

Fire was probably less harmful in pre-settlement times. There was a far greater supply of seeds since relatively old and large stands stored more seeds in the peat within the stands, as well as in adjoining areas. Frequent fires in the surrounding habitats were not intense and were less likely to penetrate the stands (Little 1950). Fires that could penetrate into these wet areas would have been hot enough to prevent sprouting by associated hardwoods. Following such a burn, the large amount of wind-distributed seed from old growth stands nearby had a good chance of restocking the areas when moisture conditions became suitable (Little 1950).

Intense fire on peat soils may not only destroy seed reserves but also lower the soil surface, causing the community to revert to a more hydric community such as cypress swamp or pocosin if the water level stays relatively stable (Little 1950, Levy 1987). Such conditions favor the development of a hardwood swamp (Buell and Cain 1943).

Fire suppression has been responsible for the vast reduction in the switch cane understory once characteristic of pond pine woodlands (Hughes 1966). Estimates of the original extent of cane dominated areas are 250,000 acres in Virginia (Frost 1989) and 2 million acres in Virginia and the Carolinas (Hughes 1966), whereas the estimate was as low as 2000 acres in 1989 (Frost 1989). It is likely that large areas that are now dominated by pond pine with dense broadleaf evergreen vegetation were once dominated by pond pine/cane (Type I community) when the natural fire regime was prevalent. An extensive area dominated by this community in North Carolina has declined greatly just since being described in 1982 (Fussel et al. 1995).

Fire suppression is a primary threat to remaining streamhead pocosin communities. Fire suppression is believed to eventually kill rough-leaved loosestrife due to shading by shrub dominance, but the endangered plant may persist for years or decades under a fairly dense shrub layer. Plow lines constructed to control fire in upland communities can adversely affect streamhead pocosin hydrology by channeling sheet flow surface water away from the site and by promoting severe erosion (Frantz 1995, Harper et al. 1997).

Fire, which has historically occurred in cypress domes during the dry seasons, is an important factor in preventing the dominance of cypress wetlands by other tree species (Cypert 1961, Gunderson 1977, Ewel and Mitsch 1978, Marois and Ewel 1983). Periodic fires will not significantly affect the species composition of normally wet domes, but does maintain cypress domination in drier domes by killing newly established slash pines and hardwoods (Ewel and Mitsch 1978, McCulley 1950). Fire may kill younger cypress but they generally resprout from the stumps (Kurz and Wagner 1953). Light burning has been observed to increase cypress regeneration while severely burned cypress swamps tend to favor regeneration of black gum (Ewel, Davis, and Smith 1989).

Firebreaks surrounding cypress domes are detrimental to the biota in this community type. Besides physically disturbing the soil and hydrology of the depression, they exclude fire that is necessary for the maintenance of habitat required for native plants and animals. Fire suppresses the development of a thick shrub layer, opens the canopy, and allows the light penetration that is necessary for herbaceous growth. Rare plants including Curtiss' sandgrass, Boykin's lobelia, and Chapman's butterwort require the open, meadow-like environment of cypress dome perimeters maintained by fire under natural conditions. Chapman's butterwort may appear upon creation of pine plantations, but disappears when three layers of vegetation close over it, probably due to shading and reduction of soil moisture (Kral 1983). In cypress ponds, the herbaceous layer that is sensitive to fire regime is also important in providing habitat to endangered amphibians (TNC 1995).

Overgrowth of shrubs and loss of the herbaceous layer due to a combination of changes in the natural hydrology and fire suppression are common factors in the degradation of basin peatland communities on DoD lands (TNC 1995, FNAI 1994a). Fire suppression in low, high, and small depression pocosins results in the reduction and disappearance of the herbaceous layer and the characteristic herbaceous openings that support most of the TES plants found in the community (Fussel et al. 1995; T. Cruise, 8 April 1996). Relatively frequent fire also is important for the release of nutrients, especially phosphorous, that are limiting in this habitat (Wilbur and Christensen 1983).

Management Recommendations

Any fire regime will favor some plant communities over others, and some species over others. Managers must first and foremost identify the landscape that they desire and apply fire appropriately through time and space to maintain the desired mix of species and community types. General information for fire management in support of different peatland communities follows.

Bay Forests. Protection from fire is required to maintain bay forests since they are late successional communities. If managers believe that a bay forest has taken the place of another, more desirable, community type, due to unnatural changes in the fire regime, then prescribed burning would be appropriate.

AWC Forests. It is clear that under natural conditions, the AWC forest is dependent upon periodic, sometimes infrequent, burns. However, under human influence, the community has largely been logged and converted to young stands, often mixed with hardwood species. Throughout most, if not all, of the AWC range, it is currently more important to retain stands and encourage old growth characteristics, than to convert additional sites to earlier stages (NCNHP and TNC 1995). Although details about the requirements of TES in AWC habitat are not readily available, there is no information suggesting that prescribed burning is necessary or desirable for TES conservation in this community. It would be unusual to identify a mature AWC stand for which protection from disturbance, at least for many decades, is not recommended on the basis of TES conservation and natural values considerations.

Pond Pine Woodlands. It is recommended that pond pine natural communities be burned at 5- to 8-year intervals. The entire area should not be burned at one time but should be divided into several burn units to prevent extirpation of insect populations (Fussel et al. 1995) and to comply with smoke regulations (T. Cruise, 18 April 1996). Growing season burns are preferable since they mimic natural fire regimes (Fussel et al. 1995). Areas with remaining stands of switch cane should be given high priority for burning and implementation of a frequent fire regime to preserve and encourage the spread of this habitat type through clonal regeneration (Hughes 1966). Five- to 8-year burn intervals should allow for habitat diversity on the landscape, since the recently-burned sites will have an almost-pure understory of switch cane, while sites that were burned earlier will have an increased shrub component to the understory (Frost 1989). Extensive areas are known where cane persists in varying densities under pond pine forest and under closed canopies of pond pine and hardwoods growing on peatland soils (Frost 1989). If cane doesn't appear (from a persistent rhizome mat) following fire, it may have to be re-introduced through cuttings or seed, since it does not have a persistent seed bank (Hughes 1966).

Basin Pocosins. Prescribed burning is recommended for low pocosins. Though the optimal fire frequency is not known, an average rotation of 20 years is suggested as an initial approximation. In North Carolina, a reduction in abundance of cranberry or northern white beaksedge is used to indicate the need for a prescribed burn (Fussel et al. 1995). In general, the need for fire can be assessed by the extent of the herbaceous openings within the low pocosin (Fussel et al. 1995; T. Cruise, 18 April 1996).

Prescribed burning for high pocosins is recommended at 5- to 8-year intervals. The entire area should not be burned at one time but should be divided into at least three burn units to prevent extirpation of insect populations (Fussel et al. 1995) and to stay within regulations for smoke production when necessary (T. Cruise, 18 April 1996). Growing season burns are preferable in that they mimic the natural fire regime (Fussel et al. 1995). Intense fires may occur in areas where flammable organic matter has built up due to fire suppression earlier in the century; in these cases, the peat may burn. Managers are attempting to control the hydrology of burn units in order to control burn intensities. The water level is managed through pumping stations and flashboard risers to allow the vegetation to burn without ignition of the peat. The water level may be raised to extinguish the fire (T. Cruise, 18 April 1996).

Streamhead Pocosins. Management of fire in streamhead pocosin habitats should consider the rare plant species present. Fire return intervals of 3 to 5 years are recommended for bog spicebush and/or rough-leaved loosestrife. Since these species require shading, additional experiments should examine whether a fire return interval greater than 5 years may be beneficial to these species. Three- to 5-year fire return intervals are recommended for Carolina asphodel as well (LeBlond, Fussell, and Braswell 1994a). Pondspice is fire tolerant but seems to respond negatively to annual or biennial fire regimes (TNC 1995), so an initial fire return interval of 3 to 5 years should be implemented and monitored. Where Carolina goldenrod occurs alone, shorter than 3-year fire intervals should be conducted experimentally. Carolina goldenrod occurs with pondspice on some installations, and in these cases, a 3- to 5-year burn cycle should be used to maintain both species (Schafale and Weakley 1990, TNC 1995). To help determine the appropriate fire frequencies for different sites and different species, a monitoring program is recommended. The program should assess natural burn frequencies when fires are allowed to invade pocosin ecotones, and the resulting effects on TES plant survival and reproduction. It is possible that the moist, shrubby end of the moisture gradient, where pondspice typically occurs, is naturally limited in its frequency despite frequent fires in the surrounding upland and further upslope, where Carolina goldenrod occurs.

All of the above species require continuously moist substrates for survival, and so maintenance of the natural hydrology of these sites is imperative. Digging ditches and creating fire plowlines that alter site hydrology should not occur in these areas. Existing fire plowlines should be filled in with native soil, if possible, without use of machinery that would cause further damage to the site.

Cypress Domes. Fire has occurred historically in cypress domes during dry periods, and is a useful management tool for maintaining desired plant composition of cypress domes. Burns of the upland-cypress dome ecotone are recommended at 2- to 5-year intervals, coupled with a monitoring program to determine the effect on rare plants and animals. When combined with restoration of natural hydrology and the removal of firebreaks, the fire regime of cypress domes should not differ from that of the surrounding pine woodlands under natural conditions. Monitoring should be designed to assess the natural burn frequencies when fires are allowed to invade cypress-upland ecotones, and the resulting effects on TES plants (FNAI 1994a). Adjustments in burn interval and intensities should be made as needed. Prescribed burning should be used to maintain a meadow-like habitat on the edges of cypress domes where Boykin's lobelia, Chapman's butterwort (Kral 1983), savanna aster (Godfrey and Wooten 1981, FNAI 1994a), and Curtiss' sandgrass (Johnson 1993) are found. Pondspice, although it is fire tolerant and can sprout from roots after burning, may be harmed by a frequency of fire that other rare plants of the habitat can endure, such as annual or biennial burns. Of course, burns conducted when pondspice are surrounded by standing water will protect the species, even if the edges of the dome successfully burn (TNC 1995).

Rehabilitation of fire-excluded cypress domes may require burning to reduce fuel loads. Burning should be done in the dormant season to minimize smoke and safety problems that would occur during the growing season (FNAI 1994a). However, winter burns should not be carried out if there is concern about harming amphibian populations, such as the endangered flatwood salamander, which deposits its eggs on grasses during the winter (TNC 1995). Ideally, burning should be conducted in the spring, specifically from March to June. This is when natural ignitions from lightning strikes have been most likely to occur under historic conditions. In Georgia and the Carolinas, spring burns are less likely to harm amphibian populations. On the Gulf coast where these habitats are wettest in the winter, spring burns would be more effective than winter burns (FNAI 1994a). Spring burns should be conducted at such a time when the surrounding habitat and dome margins would be dry enough to burn adequately, at which time salamanders are least likely to be migrating through the grassy ecotones.

In the case of a conflict between fire management recommendations for cypress domes and the surrounding upland (for example, if the cypress dome was located near a stand managed for timber or an urban area), fire may be restricted to the cypress dome site using a temporary fire line. The isolated wetland, the wetland-upland ecotone, and a buffer zone of upland forest should be included within the fire break, which is placed in the upland community. Implementing isolated burns may circumvent restrictions regarding smoke production that would otherwise discourage early growing season burns (FNAI 1994a). After the burn is conducted, the fire plowline should be revegetated with native species and managed to prevent erosion.

Hydrologic Management

Impacts

Massive disruption of wetlands hydrology has occurred over 300 years of drainage efforts throughout the southeast (Frost 1987). Some natural communities have been affected over very large areas by conversion to urban and agricultural lands, while other communities are more at risk from localized activities within a small watershed. Bay forests and other communities that occur on seepage slopes are an example of the latter. These small areas can be severely affected by use of off road vehicles (FNAI 1994a) and road construction. Off-road vehicles (ORVs) damage vegetation directly and alter the natural hydrology by rutting and compacting the soil. Once soil stability is compromised, the sandy soils form erosion gullies that channel water off the hillside. Channelization and the subsequent drainage is devastating to this community (Wharton 1978), since most wetland plants are very sensitive to slight changes in soil moisture regimes (reviewed in Harper, Trame, and Hohmann 1998). Streamhead pocosins experience similar degradation due to channelization and drainage, since the hydrology is similar to seepage slope bay forests.

Lowering the water table across landscapes that support AWC forests will result in the replacement of white cedar by species tolerant of the drier conditions (LeBarron and Neetzel 1942; Penfound 1952). Ditching near logged AWC stands has promoted rapid drying and dominance by species usually occupying drier sites (Levy 1987). In the Dismal Swamp, an extensive network of ditches and roads have lowered the water table, adversely affected the establishment and growth of white cedar seedlings, and increased the risk of fire (Akerman 1923). This drainage network also has allowed soil moisture conditions that favor establishment of hardwood species (Hickman and Neuhauser 1977). Lowering the water table may result in subsidence of peat, oxidation, and the exposure of mineral soil (Frost 1987).

Low, high, and small depression pocosins are affected by ditching and drainage of the soil. Ditching at and below the interface of the peat and mineral layer increases discharge into estuaries because base flow contribution from the mineral layer occurs (Daniel 1981). By the 1960's, most pocosins were severely dissected by drainage canals dug for the purpose of draining adjacent areas for pine silviculture (Ash et al. 1983.)

Alteration of the natural hydrologic cycle of cypress domes may reduce cypress regeneration since cypress depend on fluctuating water levels for germination (Demaree 1932, DuBarry 1963). Growth rates of cypress are highest in areas that are neither very wet nor very dry, due to the respective limitations of oxygen and water for growth (Marois and Ewel 1983). Water levels that are maintained at unnaturally high levels and not allowed to draw down during the dry season prevent establishment of cypress. Many amphibians require total draw-down at some point for reproduction, since drying out eliminates predators (TNC 1995). Limited drainage increases cypress growth rates, but the drier conditions of cypress domes that have unnaturally lowered hydrology and shorter hydroperiods are associated with changes in the plant community; hardwood species increase in importance and absolute density, shrubs increase in density, and slash pines may invade the cypress dome (Marois and Ewel 1983). These plants are not as tolerant to flooding as cypress and are restricted under natural hydrological conditions (Conner and Day 1976). Since most hardwoods may become established under lower light levels than cypress (Fowells 1965), high shrub densities in the drier cypress domes further reduce cypress regeneration by favoring competitive hardwood seedlings and saplings (Marois and Ewel 1983).

Maintenance of the natural hydrology of cypress domes is important to the rare plants found in this habitat on military installations. Boykin's lobelia, pondspice, and Chapman's butterwort require shallow standing water or wet peaty soils to persist (Godfrey and Wooten 1981, Kral 1983). Following ditching for drainage, Chapman's butterwort often lines ditches, where moisture conditions are still adequate, but the plant disappears once drainage is complete enough to dry out the site (Kral 1983). Curtiss' sandgrass inhabits shallow, temporarily flooded parts of cypress depressions and grows in a band surrounding deeper areas, suggesting it requires a specific hydrology to persist (Johnson 1993).

Since drainage through ditch construction is standard timber management practice for pinelands in poorly drained areas (Schlaudt 1955), cypress domes within these areas are often drained as well. Following drainage the ditches may be used for planting slash pine or used to facilitate drainage of surrounding pine sites. On the other hand, ditches and plowlines that circle the cypress dome, often dug for fire protection, can increase the natural water level by holding water (TNC 1995) and preventing water from seeping out through transpiration of trees in the surrounding uplands (Crownover et al. 1995). Berms of soil placed around cypress domes may also decrease water levels by restricting water flow into the cypress dome (Brown

1981). Ditches dug across cypress domes and connected to lower areas may drain the cypress dome and decrease its natural water level. Connections with other wetlands may lead to introduction of foreign fauna, including fish that are predators of native salamanders. Pine plantations around cypress domes may also lower the water table of cypress domes because they increase transpiration in the surrounding area (Marois and Ewel 1983).

Management Recommendations

Seepage slopes should be closed to all vehicular traffic (FNAI 1994a). Ditches and firebreaks should not be dug, and existing ditches and fire breaks should be filled and re-contoured using local soil.

The natural hydrologic regime of the basin pocosin habitats is desirable to prevent the community from succeeding to a different vegetational type, such as low pocosin to high pocosin or high pocosin to pond pine woodland (Ash et al. 1983).

In areas where TES conservation is a priority, fire rings and trenches around, through, and between cypress domes should be closed and revegetated to maintain the moisture regime required by TES plant species and the flatwoods salamander. Maintaining a natural hydrological regime is also necessary to implement a fire regime that supports the biota of this ecosystem. Maintenance of a natural forest structure in upland communities surrounding cypress domes will provide natural transpiration rates and therefore natural rates of water movement into and out of the cypress domes (FNAI 1994a).

Chemical Pollution

Impacts

The pocosins of the Atlantic Coastal Plain are important nutrient filters for the maintenance of water quality in rivers and estuaries, as long as water flows through them at the slow rate characteristic of the undisturbed community. The dissection of these habitats by canals dug for drainage to promote agriculture and agroforestry has reduced the ability of these wetlands to filter pollutants. Since much of the productive marsh area of the Atlantic Coastal Plain is in close proximity to pocosins, there is appropriate concern about potential pollution from pocosin development (Ash et al. 1983). Juvenile stages of aquatic organisms are dependent on stable patterns of substrate and salinity provided by the filtering action of pocosin wetlands. Nutrient enrichment increases growth of pathogenic bacteria

(Ash et al. 1983). Nutrient enrichment of this habitat allows numerous competitive species to be supported, while native species are eliminated (Ehrenfeld and Schneider 1991).

Although net water flow is in most cases outward from cypress domes into the surrounding pineland community, water flow is slow enough that any solutes, such as fertilizers and pesticides, may affect the soil and habitat if brought in from the pinelands during precipitation events (Pionke and Chesters 1973).

Management Recommendations

Water flows into cypress domes during precipitation events, and outward during drier conditions when the water table is low. Thus, fertilizers and pesticides, if used at all, should be applied to surrounding uplands during dry periods (Crownover et al. 1995).

7 Summary

Peatland plant communities are important components of the southeastern landscape, supporting at least 11 listed species and occurring on at least 19 DoD installations. Some communities, such as streamhead pocosins, seepage slope bay forests, and cypress domes, are spatially restricted to areas with the appropriate hydrologic conditions. These communities are characterized by ecologically significant ecotones with the surrounding uplands dominated by grasses and forbs under frequent fire return intervals. The basin pocosins, basin bay forests, pond line woodlands, and AWC forests often extend over very large areas (or potentially could), creating a mosaic of diverse communities, based on differences in soils, fire regime and available species for recruitment. Together, the peatland landscape supports wide-ranging carnivores such as the red wolf and the black bear, as well as numerous amphibians, indigenous insects, and wetlands or ecotonal plants.

Unfortunately, many of these communities have been drained and converted for urban and agricultural purposes; the remaining areas on DoD lands have significant value to regional biodiversity and hydrological processes, and warrant careful management. Hydrological and fire management are important issues for all of these peatland communities; logging is an important consideration for wooded and forested communities.

Hydrological management for small-scale communities such as seepage slope bay forests, streamhead pocosins, and cypress domes is conducted at the scale of the local watershed. Erosion and soil loss from roads, off-road military training, or logging operations can lead to siltation of these wetlands or rutting and diversion of the natural recharge sources for these communities. Either process leads to a long-term drying of the soils and loss of habitat for wetland species. Drying will affect fire intensities and frequencies, which most likely will cause a change to a different community type altogether. Sometimes, cypress domes are drained along with the surrounding pine woodlands when the latter are managed for timber production. Cypress are adapted to periodic flooding and drying cycles; such disruption generally reduces cypress regeneration and converts the community to mixed hardwoods. Several of the listed plant species found in cypress domes have been sensitive to alteration of hydrologic conditions.

Hydrological management for basin pocosins and bay forests, AWC forests, and pond pine woodlands is usually a landscape-level exercise. The most common alteration is a large-scale lowering of the water table due to intentional ditching and draining. This dries the peaty soils and increases fire intensities and frequencies. Changes in soil moisture have been shown to increase dominance by other species in AWC swamps.

Changes in fire regime generally alter the identity of a plant community type or its quality as TES habitat. Most communities in the southeast are adapted to fire to some degree, so a shift in fire return interval or fire frequency means that one community becomes replaced by another until previous conditions occur again. Over an entire landscape, representation of the different communities may change gradually with long-term climate change. Otherwise, a landscape is generally characterized by a shifting mosaic of communities that support TES. Excellent land management planning can allow for human activities and TES conservation by understanding and using the natural disturbance and regeneration processes of these communities. The appropriate fire regime can be generated to maintain certain communities in certain places across the landscape. For example, fire should be excluded from sites where bay forest habitat is desired. In areas where moderate- or high-quality AWC forests remain, fire should be excluded as well, since these areas are significant, rare remnants of a community that we are not certain we can restore and maintain successfully. The other peatland communities are adapted to relatively frequent fire; pond pine woodlands and the basin pocosins should be burned at 5- to 8-year intervals. Streamhead pocosins require even more frequent fire, 3- to 5-year intervals are recommended for several of the plants found in streamhead pocosin communities or their ecotones. Cypress domes naturally burn during dry periods, and the recommended interval is 2 to 5 years. If natural hydrology is restored and/or maintained, cypress domes could be maintained by allowing them to burn naturally with the surrounding pine woodlands community, under a natural regime of every 1 to 3 years (Harper et al. 1997). Any fire plow-lines required to conduct prescribed burns in peatland communities should be recontoured and revegetated once the burn is complete, to prevent serious hydrologic and erosion-related impacts to the environment.

Impacts and management considerations related to timber harvest are important for three of the peatland communities. Pond pine woodlands, cypress domes, and AWC forests may be used for logging. Heavy machinery used in cutting and extraction may lead to disruption of soils, erosion, rutting, and channeling of water through ruts. However, for each of these communities, the most significant impact from logging is an apparent lack of natural regeneration. Research has indicated several practices that may improve regeneration by AWC, including clearcutting of all trees, especially hardwoods, in areas less than 5 acres in extent, followed by clearing of all brush piles and control of hardwoods during early stand regeneration.

Appendices A through F: Detailed Ecological Description of Peatland Communities

Certain peat-forming non-alluvial palustrine wetlands that occur in the southeastern Coastal Plain are collectively called peatlands. They include communities that are fed by rainwater or highly oligotrophic (slowly moving, nutrient-poor) groundwater. Their soils are strongly acidic and are composed of peat, or otherwise are wet mineral soils with a high organic content. These habitats have in common a shrub layer of ericaceous, mostly evergreen plants (Schafale and Weakley 1990).

The following appendixes contain discussions of six categories of non-alluvial wetlands, or "peatlands." They are: bay forest, AWC forest, pond pine woodland, combined low, high and small depression pocosins, streamhead pocosins, and cypress domes.

Physical environmental factors as well as plant physiognomy are emphasized in delineating the communities discussed herein. Important factors include vegetation, peat depth, topographic setting, fire regime, and hydrology. Most of these communities have the same dominant or characteristic species and are better distinguished based upon the relative density of the shrub, herb, and tree layers as well as their relative topography.

Appendix A: Detailed Ecological Description of Bay Forest Communities

Bay forest is used to describe communities dominated by a number of bay trees (Christensen 1988). The Nature Conservancy's Southeastern United States Ecological Community Classification (Allard 1990) and state classification systems for North Carolina and South Carolina use this name to describe the community (Nelson 1986, Schafale and Weakley 1990) and mention the synonyms evergreen bay and bay pocosin. State classification schemes refer to this community as sweetbay forest (Pell 1984, Smith 1988), and red bay-sweet bay community (Penfound 1952) in Louisiana; bayhead forest (Wieland 1994) in Mississippi; and baygall (FNAI and Florida Department of Natural Resources [FDNR] 1990) in Alabama and Florida; Coastal Plain bog/seep forest when dominated by bays (Wharton 1978) in Georgia; and oligotrophic saturated forest (Rawinski 1990; cross-classified in Allard 1990) in Virginia.

Bay forests may generally be divided into those that occur on seepage slopes and those that occupy basins or non-alluvial wetlands. Those on seepage slopes share many physical characteristics with streamhead pocosins and those in basins with the other pocosin types and peatland forests. The distinction is sometimes important for management considerations.

Range/Current Distribution

This community occurs predominantly in the outer Coastal Plain (Landaal 1991a). Other occurrences are in the middle Coastal Plain, sandhills, and lower piedmont (Landaal 1991a, Schafale and Weakley 1990). The community type extends from Virginia south to Florida, and west to eastern Texas (Christensen 1988). The community also occurs in Arkansas (Landaal 1991a).

Environmental Factors

Topographic Position

Bay Forests typically occur at drainages and edges of sandhill streams, depressions in sandhills, Carolina bays (Landaal 1991a), edges of floodplains where there is groundwater seepage (Wharton 1978), and poorly drained interstream flats (Schafale and Weakley 1990). They occur on margins of deep gum and cedar swamps in the Great Dismal Swamp and in shallow cut-over cypress swamps in the Okefenokee Swamp. They can occur in shallow organic deposits and deeper peats (Schafale and Weakley 1990).

Hydrology

Bay forests are continually to seasonally saturated and infrequently flooded (Landaal 1991a, Schafale and Weakley 1990). Hydrologic inputs are from perched water tables, seepage from adjacent slopes, and rainfall, unless the community is associated with a stream (Landaal 1991a).

Natural Disturbance Regime

The community is late successional and is not maintained by disturbance (Landaal 1991a, Schafale and Weakley 1990). Saturated soils decrease the occurrence of fire. Fires that do occur are more intense when abundant vegetative biomass is present (Landaal 1991a).

Soil

Soils are strongly acidic and sandy, with a surface layer of peat. The peat can be as deep as 2 m and is high in organic matter content. In occurrences in Carolina bays and possibly elsewhere, a perched water table is maintained by an impervious layer beneath the soil (Landaal 1991a).

Physiognomy/Structure

Bay Forests are broad-leaved evergreen forests that are low in stature (for example, 3 to 10 m in height in the Green Swamp, NC) relative to surrounding forest types. The canopy is dense and there exists a subcanopy of vines and tall shrubs (Landaal 1991a). The shrub layer in North Carolina is dense to somewhat open (Schafale and

Weakley 1990). The herb layer is sparse, but sphagnum moss may be abundant. Tree roots are frequently exposed (Landaal 1991a).

Commonly Associated Plant Communities

Pond pine woodlands, non-riverine swamp forest, AWC forest and high and low pocosins often occur in a mosaic with bay forests (Landaal 1991a, Schafale and Weakley 1990, Wharton 1978).

Successional Relationships

This community is believed to be late successional, succeeding AWC swamp forest (Buell and Cain 1943) and pond pine woodland after a long period without fire. If the water table is high and there is a deep, peat-burning fire, a sedge bog can develop if fire continues to be frequent. When the water table is low, a deciduous bay forest may develop after a deep peat burn. A shallow peat burn can lead to the development of AWC swamp forest or a pond pine woodland if the seed bank contains these species (Christensen 1988, Landaal 1991a, Buell and Cain 1943). However, the community dominants recover quickly following fire, and may recover from less severe burns (Schafale and Weakley 1990).

Biological Composition

The community is characterized by the canopy dominance of one or more of the following: loblolly bay (*Gordonia lasianthus*), sweet bay (Magnolia virginiana), and swamp red bay (Persea palustris) (Landaal 1991a), but other species found in association with bay trees vary across the region (Christensen 1988). In North Carolina, pond pine (*Pinus serotina*), swamp tupelo (*Nyssa biflora*), red maple (*Acer rubrum*), loblolly pine (*Pinus taeda*), and AWC may be significant components of the canopy and sub-canopy in addition to the dominant bay species (Schafale and Weakley 1990). In Florida, pond pine, slash pine (Pinus elliottii), longleaf pine (*Pinus palustris*), and bald cypress (*Taxodium distichum*) occur in bay forests. Canopy dominants in Texas bay forests include swamp laurel oak (*Quercus laurifolia*), black gum (*Nyssa sylvatica*), sweet bay, yaupon (*Ilex* i) and red maple (Christensen 1988). In Louisiana, the canopy is similar to that in Texas, with the addition of pond cypress (*Taxodium ascendens*), slash pine, and longleaf pine. The shrub layer can be diverse, including titi (*Cyrilla racemiflora*), fetter-bush (Lyonia lucida), sweet gallberry (*Ilex coriacea*), bitter gallberry (*I. glabra*), evergreen bayberry (*Myrica heterophylla*), black highbush blueberry (*Vaccinium atrococcum*), highbush blueberry (*V. corymbosum*), zenobia (*Zenobia pulverulenta*) (Christensen 1988), wax myrtle (*Myrica cerifera*), male-berry (*Lyonia lugustrina*), leucothoe (*Leucothoe axillaris, L. racemosa),* Virginia willow (*Itea virginica*), red chokeberry (*Sorbus arbutifolia*), possum-haw viburnum (*Viburnum nudum*), poison sumac (*Rhus vernix*), sweet pepperbush (*Clethra alnifolia*), hazel alder (*Alnus serrulata*), American snowbell (*Styrax americana*), summer azalea (*Rhododendron serrulatum*), wild azalea (*Rhododendron oblongifolium*) (Smith 1988), and sparkle berry (*Vaccinium corymbosum*) (Ewel, Davis, and Smith 1989). Vines, including greenbriar (*Smilax spp.*), Carolina jessamine (*Gelsemium sempervirens*) and Virginia creeper (*Parthenocissus quinquefolia*) are important components of bay forests (Christensen 1988). Herb species include netted chainfern (*Woodwardia areolata*), cinnamon fern (*Osmunda cinnamomea*), and royal fern (*Osmunda regalis*) (Landaal 1991a, Christensen 1988).

Appendix B: Detailed Ecological Description of Atlantic White Cedar Forest Communities

There are several different names for this plant community. Atlantic white cedar (AWC) swamp is the name used in classifications for Alabama and South Carolina (Nelson 1986). In the classification for Mississippi, this community is synonymous with white cedar forest or cedar bog (Penfound 1952). In North Carolina, this community type is further divided into two types: peatland AWC forest and streamhead AWC forest (Schafale and Weakley 1990). In Florida's classification system, AWC forests are types of bottomland forests (FNAI and FDNR 1990). In Virginia's classification, they are a type of mesotrophic saturated forest (Rawinski 1990).

Range/Distribution

AWC forests occur throughout the Coastal Plain, primarily in the peatlands of the outer Coastal Plain, but also on the middle Atlantic Coastal Plain (Landaal 1991b, Schafale and Weakley 1990). According to Landaal (1991b), the range of this type is the same for that of AWC, occurring in a narrow coastal range 50 to 130 miles wide from southern Maine to northern Florida and west to southern Mississippi. However, this species only forms extensive stands in a few areas, including the New Jersey pine barrens, the lower terraces of North Carolina and Virginia Coastal Plains, and northern Florida (Christensen 1988).

Environmental Factors

Topographic Position

AWC swamp forests are usually associated with deep peats; often peats occurring over sandy substrates (Christensen 1988). They are found on shores of lakes, rivers, streams, or estuaries in isolated basins, or on seepage slopes or streamheads (Schafale and Weakley 1990, Moore and Carter 1987). They may also occur on islands in lakes and rivers (Landaal 1991b). In North Carolina, AWC swamp forests occur on the outer parts of domed peatlands on poorly drained interstream flats. They also occur on shallow peat-filled Carolina bays and swales (Schafale and Weakley 1990). They are typically in drier locations than other pocosin types (Schafale and Weakley 1990). In Florida, they occupy valleys of small streams through deep sandhills where soils are perennially moist or wet from constant seepage of groundwater, but are only briefly, if at all, flooded. They have also occupied boggy pine flatwoods near the coast in panhandle Florida (Clewell and Ward 1987).

Hydrology

AWC seedlings are intolerant of flooding, and adults cannot tolerate much flooding. Authors have described these forests as occurring in nontidal, seasonally flooded, saturated, semipermanently flooded, or permanently flooded areas (Landaal 1991b) and areas with or without flowing or seepage water (Schafale and Weakley 1990). The water table in AWC forests characteristically fluctuates between highs of 20 to 30 cm above the surface of the bottoms of the deepest hollows in the microtopography to 20 cm below the surface (Golet and Lowry 1987, Ehrenfeld and Schneider 1991). Because of the hummocky microtopography of this habitat, different surfaces experience different degrees of inundation and moisture. In one study of a natural AWC forest, 25 percent of the area was likely to be regularly flooded every year, 25 percent was within the likely range of variation in high water levels, and 50 percent was unlikely to experience flooding except during unusually wet years, when it would experience, at most, soil saturation during periods of high water (Ehrenfeld 1995). Under undisturbed conditions, AWC forests may be flooded and have shallow standing water in depressions from mid-winter to mid-summer with seasonal high water occurring in early spring (Moore and Carter 1987, Ehrenfeld and Schneider 1991). The duration and depth of the hydrologic regime varies with precipitation, however, and there is considerable variability among sites (Ehrenfeld and Schneider 1991, Golet and Lowry 1987).

Disturbance Regime

AWC does not establish under the shady conditions of mature stands. Thus, this community is dependent on the open conditions created by intense crown-killing fire (Christensen 1988, Landaal 1991b, Schafale and Weakley 1991), clearcutting, extensive windthrow (Little 1950, Moore and Carter 1987) or flooding (Moore and Carter 1987). Although hurricane or tornado blowdowns may fell substantial tracts, only fire could be expected to kill standing timber and remove debris, exposing the open seedbed for regeneration (Frost 1987). The community regenerates best after a light fire on bare mineral soil, as this removes competing vegetation and allows the viable seeds in the seed bank to survive; a fire that burns deep into the peat may destroy the seeds (Landaal 1991b, Schafale and Weakley 1991). Fire return intervals ranging from 25 to 250 years may be necessary for regeneration (Frost 1987).

In the Gulf Coast populations of AWC, gap regeneration may be more important than regeneration after fire (Clewell and Ward 1987). Fire is seldom observed in this area because seepage saturated soils and broad-leaved understory vegetation suppress fire initiated by lightning strikes and other sources (Ward and Clewell 1989). As a result, other disturbances that create open conditions, such as flooding, windthrow, and logging, are necessary for regeneration on the Gulf Coast (Landaal 1991b). Most white cedar seedlings in a gap die following closure of the canopy. Infrequently, a second gap in the canopy develops before all of the seedlings of a cohort have died; this allows the survivors to grow as long as suitably spaced breaks in the canopy continue to exist. As they grow, they are better able to survive periods of reduced light and become permanently established upon reaching the canopy. Once becoming emergent in the canopy, however, the trees become susceptible to lightening, which is their most common cause of death (Clewell and Ward 1987).

Soil

The community usually occurs on peat soils underlain by sand (Buell and Cain 1943). It has been observed that the proportion of swamp hardwoods in cedar stands increases with the amount of silt and clay in the subsoil (Korstain 1924), although Laney and Noffsinger (1987) did not find such a correlation in Dare County, NC. Soils are more sandy in AWC swamp communities along the Gulf Coast than the Atlantic Coast (Landaal 1991b).

Physiognomy/Structure

In the Carolinas and Virginia, this community typically exhibits a dense, even-aged canopy dominated by AWC. In these areas, shrub and herb layers are relatively open (Landaal 1991b). The even-aged type probably reflects regeneration after large-scale disturbance such as fire, more common in the northern part of the range (Landaal 1991b). In the Gulf states, AWC shares dominance with a variety of species (Christensen 1988), and stands are not even-aged (Landaal 1991b). Shrub cover may exceed 80 percent in the understory (Christensen 1988). The herbaceous layer is composed of sphagnum moss and ferns (Christensen 1988). The uneven-aged mixed-species stands typical of the southern AWC forests are a consequence of gap succession in the absence of fire (Clewell and Ward 1987).

Commonly Associated Plant Communities

This community may occur in a mosaic with pond pine woodland, bay forest, other pocosin types (Landaal 1991b), and non-riverine swamp forests (Schafale and Weakley 1990). Near shorelines it may grade into estuary-fringe, loblolly pine forest, tidal cypress-gum swamp, or marsh communities. Streamhead types grade abruptly into sandhill or wet pine flatwoods, or small stream swamps along stream courses (Schafale and Weakley 1990).

Successional Relationships

This community is early successional but consists of long-lived trees. AWC lives to be more than 250 years old (Frost 1987). The community usually succeeds itself following fire, as long as the fire is not so hot that it kills the seed bank. In dry periods when fire causes the upper peat layer to burn, the community may be replaced by other pocosin types, gum-cypress swamp (Ash et al. 1983), or a pure stand of slash pine (Garren 1943). In the absence of fire this community may succeed into bay forest or a more species-rich swamp community (Landaal 1991b), although this is not well documented and the time for this to occur in the absence of logging is not well known (Fussel et al. 1995). Weakley and Schafale (1991) also suggest that AWC swamp forest can succeed into pond pine woodland in North Carolina.

Biological Composition

This community is dominated by AWC (*Chamaecyparis thyoides*) occurring in pine or mixed stands. In mixed stands, characteristic subdominants include red maple (*Acer rubrum*), sweet bay (*Magnolia virginiana*), and swamp tupelo (*Nyssa biflora*) (Landaal 1991b). The shrub layer is often dominated by sweet pepperbush(Clethra alnifolia) and highbush blueberry (*Vaccinium corymbosum*) (Landaal 1991b), but can also include fetter-bush (*Lyonia lucida*), sweet gallberry (*Ilex coriacea*), bitter gallberry (Ilex glabra), and red bay (*Persea borbonia*) (Christensen 1988). Peat moss (Sphagnum sp.) and Virginia chainfern (*Woodwardia virginica*) are important species in the herb layer (Christensen 1988), as are partridge berry (*Mitchella repens*) and poison ivy (*Rhus toxicodendron*) (Landaal 1991b).

Appendix C: Detailed Ecological Description of Pond Pine Woodland Communities

Pond pine woodland is the name used for this community in classification systems for North Carolina (Schafale and Weakley 1990) and South Carolina, and it is synonymous with pond pine forest in those states (Nelson 1986). In Virginia's classification, pond pine woodland is a type of oligotrophic saturated or seasonally flooded woodland (Rawinski 1990). In Florida's classification, this community is a type of wet flatwoods (FNAI and FDNR 1990), and in Georgia's classification, it is a type of Coastal Plain bog/seep forest (Wharton 1978). Other names include pine swamp, pine bog, and pine pocosin (Penfound 1952).

Range/Distribution

This community occurs on the Coastal Plain from Florida to Virginia (Landaal 1991c). In North Carolina, this community is most extensive on the outer parts of the Coastal Plain (Schafale and Weakley 1990).

Environmental Factors

Topographic Position

Pond pine woodlands occur on the outer parts of domed peatlands on poorly drained interstream flats (Landaal 1991c). They also occur on shallow, peat-filled Carolina bays and swales (Schafale and Weakley 1990).

Hydrology

This community has a long hydroperiod, but the water table drops below the peat layer during the dry season, which allows plants to root below the peat (Landaal 1991c, Schafale and Weakley 1990). In North Carolina, plants in this community may also receive water with nutrients from adjacent communities. The community occurs in areas that are drier than low and high pocosins (Schafale and Weakley 1990).

Disturbance Regime

Fire in pond pine woodlands has been reported to occur during dry periods every 10 to 20 years (Landaal 1991c). However, historical reports going back to the times of the colonists describe the fire interval as 3 to 5 years (Hughes 1966), and even poorly drained areas have seldom burned less frequently than every 5 years (Wells 1942). Frost (1989) describes a fire regime of 3 to 5 years as ideal for the continuation of a pure canebrake understory that was once common. Fire regimes of 5 to 18 years result in alternation of cane understory and pocosin shrub understory on peat from 0.5 to 1 m deep (Frost 1989). Because of their drier position on the landscape, pond pine woodlands burn more frequently than low and high pocosins. Fires can be intense due to the buildup of large amounts of fuel between fires (Schafale and Weakley 1990). Pond pine is a good example of a fire adapted species. It is able to sprout from either the roots or epicormic buds along the bole, producing the gnarled form of growth exhibited by the species. Its cones, remaining closed from 2 to 10 years after seed maturation, open upon being burned, although they do eventually open in the absence of fire (Ash et al. 1983). Switch cane, which once dominated these understories, requires a fire regime of about 10 years or less to be maintained (Hughes 1966). Fires in this community are most likely to occur during the growing season. However, in recent decades, most fires have occurred during April and May. Because of the heavy fuel loads, fires in pond pine woodland have the potential to be extremely intense. Like the recovery of the pines themselves, shrub vegetation generally recovers to its former height in a few years. Fire may burn through the peat as it kills much or all of the above-ground vegetation. Fires may change the relative species composition, favoring those that recover first, such as cane. Species diversity is highest after a fire event and gradually declines thereafter (NCNHP and TNC 1995).

Soil

This community occurs on acidic, shallow, organic soils or on deeper peats. Most Florida sites have an organic hardpan or clay layer beneath the surface (Landaal 1991c). They are presumably less nutrient deficient than low and high pocosins because of the mineral influx brought in by sheetflow (NCNHP and TNC 1995). Increases in the amount of silt and clay are correlated with an increased site index for pond pine (Coile 1952). Site indices of pond pine increase with the decreasing organic matter content of the A1 horizon (Hofman 1949, Zahner 1951).

Physiognomy/Structure

Canopy density can vary from very dense to savanna-like with scattered pines and palms over a grassy understory (Landaal 1991c). The shrub layer is dense and tall (over 5 m) except immediately following fire. The shrub layer may be lost if the fire interval is too short. If fire consistently occurs more often than every 5 years, cane (*Arundinaria gigantea* or *A. tecta*) can dominate the understory. Cane dominated the understory of pond pine woodlands over vast areas in the past, but rarely do today (Hughes 1966, Fussel et al. 1995). The density of cane seems to be controlled primarily by fire regime, with minor secondary effects of organic soil depth and fertility. With fire regimes of 3 to 5 years, pure cane may be maintained; however, fire regimes of 5 to 18 years result in alternation between pure cane, immediately following fire, and pocosin shrub with occasional stems of cane concealed by the shrub canopy. Besides occasional pond pines there may co-exist some blaspheme vine (*Smilax laurifolia*), poison ivy (*Rhus toxicodendron*) or dewberry (*Rubus hispidus*) (Frost 1989). The herb layer is generally sparse (Schafale and Weakley 1990).

Commonly Associated Plant Communities

Plant communities closely associated with pond pine woodlands are other pocosin types, non-riverine swamp forests, pine flatwoods (Landaal 1991c), and pine savannas (Schafale and Weakley 1990). Ponds may occur as inclusions into pond pine woodlands where the peat has been burned down to the mineral soil (Landaal 1991c).

Successional Relationships

This community is early successional and usually replaces itself following fire. In the absence of fire, this community will be encroached upon by bays in the understory and succeed to a bay forest (Landaal 1991c). When fire frequency was much higher, large areas of this habitat were dominated by cane in canebrakes. Increased fire frequency may lead to a cane-dominated understory.

Biological Composition

Pond pine (*Pinus serotina*) forms an open to nearly closed canopy. Within its range, loblolly bay (*Gordonia lasianthus*) is a canopy co-dominant with pond pine. Sweet bay (*Magnolia virginiana*), red maple (*Acer rubrum*), loblolly pine (*Pinus taeda*) and AWC may also occur in the canopy or the understory (Landaal 1991c, Schafale and Weakley 1990). The subcanopy or shrub layer is dominated by titi (*Cyrilla racemiflora*), fetter-bush (*Lyonia lucida*), sweet gallberry (*Ilex coriacea*), and swamp red bay (*Persea palustris*) (Landaal 1991c). Common vines are blaspheme vine and coral greenbriar (*Smilax walteri*) (Landaal 1991c). Herbs are generally nearly absent, but may include Virginia chainfern (*Woodwardia virginica*), netted chainfern (*Woodwardia areolata*), and peat moss (*Sphagnum sp.*) clumps (Landaal 1991c, Schafale and Weakley 1990). Switch cane once dominated large areas of the herb layer of this habitat, although it is uncommon today (probably because of suppression of fire, Schafale and Weakley 1990).

Appendix D: Detailed Ecological Description of Basin Pocosin Communities

Low and high pocosins are discussed together because they grade into one another in the landscape, and small depression pocosins have similar physical and floristic characteristics. Low pocosins occur in areas of deeper peat (usually 1 to 5 m deep) than high pocosins (peat depth of 1.5 m or less), otherwise both communities occur on oligotrophic wet sands (Schafale and Weakley 1990).

Pocosin communities differ in species composition and name throughout their range. These pocosins are included in the pine-ericalean pocosin type (Kologski 1977). They are also referred to as a type of evergreen shrub bog (Wharton 1978). Low and high pocosins are referred to under the same names in North Carolina's classification (Schafale and Weakley 1990) and as short and tall shrub bogs in Georgia's classification (Wharton 1978). Nelson (1986) combines these types as pocosin in South Carolina. Similarly, Ambrose (1990) calls these communities Coastal Plain shrub bog/seeps in Georgia. Penfound (1952) calls them evergreen shrub swamp or Ilex-Cyrilla-Zenobia community in Louisiana. In Virginia, low pocosins are called palustrine dwarf scrubs (Rawinski 1990), while high pocosins are called oligotrophic scrub (Rawinski 1990). Florida calls high pocosin a bog (FNAI and FDNR 1990). Small depression pocosins are called so in North Carolina (Schafale and Weakley 1990), while they are called swale pocosin in South Carolina (Nelson 1986), and correspond to Grady pond forest in Mississippi (Wieland 1994).

Range/Distribution

These pocosins occur primarily in the outer Coastal Plain and less commonly in the inner Coastal Plain. Low pocosins are mostly restricted to North Carolina (Schafale and Weakley 1990). The range of these communities extends from Virginia to Florida (Doyle 1990c). Small Depression Pocosins occur in isolated areas throughout the Coastal Plain and sandhills in North Carolina and South Carolina (Doyle 1990a, Schafale and Weakley 1990). Similar vegetation thought to represent this community type also occurs in Mississippi, Georgia, Florida, and Virginia (Doyle 1990a).

Environmental Factors

Topographic Position

Low pocosin occurs in the centers of extensive outer Coastal Plain interstream peatlands ("peat domes"), and grades into high pocosin, which occurs on the margins of these domes. Additionally, high pocosin occurs in the middle Coastal Plain in peat-filled Carolina bays and swales; low pocosin occasionally occurs in this situation (Doyle 1990b, c; Schafale and Weakley 1990). In Georgia, pocosins are described as occurring on downslopes protected from fire, usually at the base of clay ridges or sandhills (Wharton 1978). Small depression pocosins occupy isolated depressions in upland community types and may be surrounded by sand ridges (Doyle 1990a). They are commonly seasonally flooded or saturated (Schafale and Weakley 1990).

Hydrology

The hydrology is palustrine, seasonally flooded, or saturated (Schafale and Weakley 1990). The water table stays close to the soil surface throughout winter and early spring due to low rates of evaporation and transpiration (Campbell and Hughes 1991). Flooding usually occurs in the early spring (Penfound 1952). Later in the spring, high temperatures, wind, evaporation, transpiration, and low rainfall produce a rapid drop of the water table. Although late summer thunderstorms or hurricanes may maintain high water table levels, the lowest water table levels usually occur in early fall (Campbell and Hughes 1991). No water drains into low pocosins as they occupy the centers of domed peatlands and are higher than surrounding land; little water may drain into high pocosins from low pocosin areas. Thus, these communities are completely or largely ombitrophic (receive all nutrient inputs from rain and dryfall).

Disturbance Regime

These communities are fire-dependent. Severe fires associated with droughts occur periodically under natural conditions; from 3 to 8 years in "high diversity" pocosins and less frequently in those dominated by titi (*Cyrilla racemiflora*; Wharton 1978). Ground fires, or those burning the peat itself, can kill much or all of the above-ground vegetation (Doyle 1990b, c; Schafale and Weakley 1990). A single fire set or lightning strike fire may alter vast areas of low and high pocosins (Cruise 1996). Fires in low pocosins of Dare Bombing Range, NC, have usually occurred in April and May. They typically kill all above-ground vegetation structure while most underground parts survive. Plants resprout and the recovery of vegetation structure and biomass is rapid after fire. Severe fires during droughts may burn into the peat, killing roots and creating small patches where hydrology has been altered. Species diversity and productivity are highest after fire, and they gradually decline thereafter (NCNHP and TNC 1995). Since small depression pocosins are nested within other communities, their fire regime varies with that of the surrounding habitat (Doyle 1990a).

Soil

These pocosins occur on soils ranging from wet, peaty sands to peat that is 5 meters deep, with low pocosins occurring on the deepest peat. Low pocosins are the most nutrient poor because of their ombitrophic position. Small depression pocosins are likely to be more fertile than other pocosin types because they can receive nutrients released by fires in surrounding communities (Schafale and Weakley 1990).

Physiognomy/Structure

Low pocosins are dominated by shrubs less than 1.5 meters in height, but may contain distantly spaced, stunted, and gnarled pond pine. High pocosins have a shrub layer that ranges from 1.5 to 3 m tall. High pocosins have scattered bay shrubs and hardwood species that form a subcanopy, and they may exhibit an open canopy of pond pine. Small depression pocosins may resemble either low or high pocosins in their physiognomy (Doyle 1990a).

Commonly Associated Plant Communities

Low pocosins grade into high pocosins, which grade into pond pine woodlands. At the edges of depressions, high pocosin may grade into a drier, non-pocosin community (Schafale and Weakley 1990). Pocosins may occur along the drier edge of bay swamps, or they may form a ring around cypress ponds (Wharton 1978). They may also grade into sandhill terrain, increasing in species diversity with higher fire frequency. In North Carolina, they may grade into gum-cypress swamps, as well as long leaf pine savanna and its associated herb bog community (Ash et al. 1983). Small depression pocosins are isolated inclusions within pine flatwoods or longleaf/turkey oak sandhills (Schafale and Weakley 1990).

Successional Relationship

High pocosin may succeed into bay forest in the absence of fire. Low pocosins do not appear to succeed to other communities in the absence of fire (Christensen 1988). Some high pocosins may once have been dominated by cane (Arundinaria sp.) brakes in times of more frequent fire, as they still have these as inclusions (T. Cruise, 18 April 1996). In Georgia, pocosins have been observed to succeed to grass-sedge savanna following severe fire (Wharton 1978).

Biological Composition

Low Pocosins

A canopy of widely scattered and stunted pond pine (*Pinus serotina*), swamp red bay (*Persea palustris*), loblolly bay (*Gordonia lasianthus*), and sweet bay (*Magnolia virginiana*) often occurs. The dense shrub layer is usually dominated by fetter-bush (*Lyonia lucida*), titi, zenobia (*Zenobia pulverulenta*), or gallberry (*Ilex sp.*). Blaspheme vine (*Smilax laurifolia*) is common. Pools or openings dominated by leatherleaf (*Cassandra calyculata*), Walter's sedge (*Carex walteriana*), Virginia chainfern (*Woodwardia virginica*), yellow pitcherplant (*Sarracenia flava*), bushy beardgrass (*Andropogon glomeratus*), peat (*Sphagnum sp.*), and, rarely, cranberry (*Vaccinium macrocarpon*) may occur within the low pocosin (Schafale and Weakley 1990).

High Pocosins

In North Carolina, the canopy/subcanopy usually consists of pond pine (<25% cover), swamp red bay, loblolly bay, and sweet bay (Schafale and Weakley 1990). Red maple (*Acer rubrum*), swamp tupelo (Nyssa biflora), and sweet gum (*Liquidambar styraciflua*) may also occur across the range of this community (Doyle 1991b). In North Carolina, the shrub layer is dominated by fetter-bush, titi, and zenobia. Regional shrub dominants may also include red bay (*Persea borbonia*). Greenbriar (*Smilax sp.*), especially blaspheme vine, are also common in high pocosins. Switch cane (*Arundinaria tecta*) may occur. Herbs are generally absent, but in recently burned sites, Virginia chainfern and bushy beardgrass may occur (Schafale and Weakley 1990).

Small Depression Pocosins

These communities have a sparse to dense canopy that may include pond pine, red maple, swamp red bay, sweet bay, pond cypress (*Taxodium ascendens*), loblolly pine (*Pinus taeda*), and loblolly bay. The dense shrub layer consists of fetter-bush, titi, bitter gallberry (*Ilex glabra*), sweet gallberry (*I. coriacea*), sweet pepperbush (*Clethra alnifolia*), dangleberry (*Gaylussacia frondosa*), myrtle-leaved holly (*Ilex myrtifolia*), highbush blueberry (*Vaccinium corymbosum*) and Carolina sheepkill (*Kalmia carolina*); wetter areas may support zenobia and leatherleaf. Blaspheme vine and wild sarsaparilla (*Smilax glauca*) may be common. The sparse herbaceous layer may include cinnamon fern (*Osmunda cinnamomea*), Virginia chainfern, netted chainfern (*Woodwardia areolata*), and sedge (*Carex spp.*) (Doyle 1990a, Schafale and Weakley 1990).

Appendix E: Detailed Ecological Description of Streamhead Pocosin Communities

Names for this community in the Carolinas include streamhead pocosin, sandhill seep, and seepage pocosin (Nelson 1986, Schafale and Weakley 1990). Other synonyms are seepage slope in Florida (FNAI and FDNR 1990), Coastal Plain shrub bog/seep in Georgia (Wharton 1978), mesotrophic saturated scrub in Virginia (Rawinski 1990), and semi-evergreen broadleaf acid seep forest in Louisiana and Texas (Bridges and Orzell 1989).

Range/Distribution

Streamhead pocosins do not occur in the Mississippi alluvial plain, but otherwise occur in scattered locations throughout the upper Coastal Plain and fall-line sandhills. Their range extends from southeastern Virginia to northern Florida and west to southeastern Alabama (Martin 1992).

Environmental Factors

Topographic Position

This community occurs in headwaters of small streams in sandhill areas, on flat bottoms surrounding creek heads, and on adjacent seepage slopes (Martin 1992, Schafale and Weakley 1990).

Hydrology

This community receives oligotrophic runoff and seepage from pocosins and sandhills. Like other pocosins, the hydrology is palustrine and the community is seasonally to semipermanently saturated (Schafale and Weakley 1990).

Fire Regime

Streamhead pocosins are influenced by fire in uplands because of their long, narrow shape. Fire is frequent along the edges, but streamhead pocosins are usually too wet to carry fire (Martin 1992, Weakley and Schafale 1991).

Soils

Soils consist of an organic layer overlying or embedded with clay or sand, or wet, seepy sands underlain with clay (Schafale and Weakley 1990). The peat layer, when present, rarely exceeds 30 cm in depth (Martin 1992). These communities receive nutrients from adjacent uplands through groundwater and thus are more fertile than peatland pocosins (Schafale and Weakley 1990).

Physiognomy/Structure

Streamhead pocosin communities are characterized by having a scattered to very dense canopy, a dense shrub layer, and a less sparse herb layer than other pocosin types (Martin 1992, Schafale and Weakley 1990). Infrequently burned streamhead pocosins tend to have greater concentrations of trees and shrubs and fewer herbs than frequently burned examples (Martin 1992).

Commonly Associated Plant Communities

Streamhead pocosins grade upland into sandhill seeps, pine flatwoods, and longleaf pine/turkey oak sandhills (Schafale and Weakley 1990). They grade downstream into Coastal Plain small stream swamps (Schafale and Weakley 1990). They are also associated with AWC swamp forests, bay forests, and beech-magnolia forests (Martin 1992).

Successional Relationships

Under circumstances that are not clear, streamhead pocosins may develop into AWC swamp forest (Schafale and Weakley 1990). In the absence of fire over periods ranging from 20 to 50 years, succession to bay forest or Coastal Plain small stream swamp may occur (Martin 1992). Frequent fire (more often than every 5 years) may lead to the development of an herbaceous bog community at streamhead locations (Martin 1992).

Biological Composition

The canopy consists primarily of pond pine (*Pinus serotina*) and sweet bay (*Magnolia virginiana*); but may also include slash pine (*P. elliottii*), loblolly pine (P. taeda), swamp red bay (*Persea palustris*), tulip tree (*Liriodendron tulipifera*), red maple (*Acer rubrum)*, swamp tupelo (*Nyssa biflora*), black gum (*N. sylvatica*), and AWC (Martin 1992). The shrub layer is dominated by titi (*Cyrilla racemiflora*), buckwheat tree (*Cliftonia monophylla*), and fetter-bush (*Lyonia lucida*) (Martin 1992). In North Carolina, netted chainfern (*Woodwardia areolata*), cinnamon fern (*Osmunda cinnamomea*), and sedge (*Carex spp.*) are typical herbs (Schafale and Weakley 1990).

Appendix F: Detailed Ecological Description of Cypress Dome Communities

Cypress dome communities are described using several different names, including cypress domes (Brown 1981), cypress heads (Monk and Brown 1965), dome swamps (FNAI and FDNR 1990), and cypress ponds (Ewel, Davis, and Smith 1989).

Range/Current Distribution

Cypress domes are distributed throughout Florida and along the Atlantic Coastal Plain within pine flatwoods ecosystems (Crownover et al. 1995).

Physical Factors

Topographic Position

Cypress domes occur in shallow, probably karstic (Crownover et al. 1995) depressions within pine flatwoods (Marois and Ewel 1983). Their size ranges from 100 m to more than 2 kilometers in diameter (Monk and Brown 1965). Their elevation ranges from 3 to 30 meters above sea level (asl; Kurz and Wagner 1953).

Hydrology

In general, cypress domes contain stagnant water less than a meter deep, the level of which may fluctuate widely in the course of a year. They are generally wet during the summer months and may be dry for several months during the dry winter and spring (Monk and Brown 1965, Brown 1981, Crownover et al. 1995). They often have an underlying clay layer that impedes drainage (Monk and Brown 1965, Brown 1981). There are generally no surface outlets for water flow (Brown 1981), although water may also seep through cypress domes in one direction along a broad topographic gradient (Crownover et al. 1995). Water loss from cypress domes occurs mainly from evapotranspiration rather than lateral or deep vertical seepage (Ewel and Smith 1992). When it occurs, movement of water into or out of cypress domes is very slow (Crownover et al. 1995), and was approximated by

Riekerk (1992) to be 12 cm per day. Although cypress domes may collect water running in from surrounding uplands during precipitation events, net water flow is usually outward (Crownover et al. 1995). This is due to differential transpiration in the cypress dome compared to the surrounding pineland habitat (Crownover et al. 1995), as well as the differential storage of water as surface or soil water (Heimburg 1984). Outward flow increases as the water table decreases (Crownover et al. 1995).

Fire Regime

Cypress domes are susceptible to fire, especially if embedded in fire-prone pinelands. Fire susceptibility is greater if water levels are reduced and if there is a high quantity of organic material on the forest floor (Brown 1981). Although the natural fire regime of cypress domes is unknown, the edges of cypress domes burn as often as the surrounding pinelands. Fire frequency decreases towards the center of the dome with increasing moisture, and very rarely reaches the center (Kurz and Wagner 1953).

Soil

The soils of cypress domes are generally developed in acid sands and clays (Monk and Brown 1965). Cypress domes studied by Marois and Ewel (1983) have a thin, peaty O horizon, an A1 horizon of black sandy loam high in organic matter, an A2 horizon of leached sand, and a B horizon of gray sandy clay loam. Mineral concentration, organic matter, and clay content in the soils generally increase from the edge to the center of the dome (Monk and Brown 1965). Cypress buttresses often accumulate organic debris forming thick mats that provide a growth platform for many small woody and herbaceous plants (Monk and Brown 1965). The pH of the water generally ranges from 3.6 to 4.4 (Brown 1981).

Nutrients

Nutrients in cypress domes in general have a low availability due to the highly acidic conditions. Calcium ranges from 20 to 30 parts per million (ppm), magnesium from 10 to 20 ppm, potassium from 5 to 30 ppm, and phosphorus from 1 to 5 ppm (Monk and Brown 1965). Phosphorus is believed to be the most limiting nutrient, entering the cypress dome only through rainfall under natural conditions (Brown 1981).

Physiognomy/Structure

These communities appear to have a dome shape, from which they are named, because the tallest cypress trees grow in the center of the depression with tree height decreasing towards the edge. The herbaceous and shrub layers may range from very sparse to dense (Brown 1981). Typically shrubs are most dense on mats of organic matter accumulating at the base of cypress trees and are infrequent on the peaty mud in between. A herbaceous layer of ferns, forbs, and grasses is typical (Monk and Brown 1965).

Commonly Associated Plant Communities

Cypress domes are usually embedded in pine flatwoods (Abrahamson and Harnett 1990). They may also be adjacent to mixed bottomland hardwood forests or bayheads (Monk and Brown 1965).

Succession

The dominant forces influencing changes in cypress dome communities are hydrology and fire regime. Shallow water provides conditions more favorable for successful competition by evergreen hardwoods and pines. This may result from either unnatural alteration of the hydrology or accumulation of peat. When cypress domes are burned at moderate intensity, mature cypress trees survive and hardwoods and pines are killed, leaving cypress as the dominant species (Ewel and Mitsch 1978). Following a severe burn, especially following clearcutting, cypress may not regenerate and the cypress dome will become dominated by willow or titi (Gunderson 1984).

Biological Composition

Most cypress domes are floristically similar. Pond cypress (*Taxodium ascendens*) is the dominant canopy tree. Swamp tupelo (*Nyssa biflora*) occurs occasionally (Marois and Ewel 1983) and may be the dominant subcanopy tree (Brown 1981). Other tree species sometimes present in the domes are slash pine (*Pinus elliottii*), swamp red bay (*Persea palustris*), sweet bay (*Magnolia virginiana*) (Brown 1981), and sweet gum (*Liquidambar styraciflua*) (Monk and Brown 1965). The major species present in the understory are fetter-bush (*Lyonia lucida*), wax myrtle (*Myrica cerifera*), bitter gallberry (*Ilex glabra*), Virginia willow (*Itea virginica*), blueberry (*Vaccinium spp.*) (Brown 1981), red maple (*Acer rubrum*), loblolly bay (*Gordonia lasianthus*) (Marois and Ewel 1983), buttonbush (*Cephalanthus occidentalis*), and dahoon (*Ilex cassine*) (Ewel, Davis, and Smith 1989). Virginia chainfern (Woodwardia virginica) is usually the dominant herb, and others common herbs include lizard's tail (*Saururus cernuus*), red-root (*Lachnanthes tinctoria*), peat moss (*Sphagnum spp.*), (Monk and Brown 1965) and *Panicum spp.* grasses (Brown 1981).

Appendix G: Community Quality Evaluation and Management

Baseline Data

To practice sound ecosystem management while satisfying the goals of the mission, protecting rare species, and producing forest commodities, installations should gather the following baseline information on which they can make management decisions.

- Locations and sizes of rare species populations or significant features within communities.
  This will allow managers to avoid direct impacts to rare species or significant features when possible, by planning potentially destructive activities away from rare species populations, and educating personnel to avoid impacting rare species when possible. This information can also be used to monitor effects of management practices on elements of concern.

- Kinds of plant communities and the juxtaposition of different communities within the landscape.
  Managers also should be aware of the relationship between plants and animals in each community and the watersheds on which they depend. Knowledge of the types of communities present in an ecosystem is important for ecosystem-based management. This knowledge, along with that of species and their relationship to watersheds, can help managers plan activities so that they cause the least disturbance to elements of concern. For example, managers should avoid creating a barrier between terrestrial habitat for a rare animal species and the watershed it depends upon for breeding.

- Quality and significance of plant communities on the installation.
  This information should be used to determine which communities have the highest priority for protection, from a biodiversity/natural heritage standpoint. A community is generally deemed high quality if it resembles presettlement conditions. Regardless of quality, the community may be highly significant based on rarity or uniqueness of the type.

Monitoring

Managers should monitor the effects of their management practices on the communities or the features of interest. For the purpose of long-term monitoring, standardized sampling methods should be developed and used. Being able to quantify improvement or degradation of habitats over time can be important to making management decisions, as well as evaluating management practices. Methods as simple as establishing permanent plots or grids are useful for repeated surveys. Aerial photographs can be used to monitor landscape and community changes over time. Keeping accurate records of land use (e.g., detailed notes of fire occurrence and species response, as well as clearcutting techniques, etc.) is also important. For a thorough description of methods for monitoring of a rare plant population and determination of its habitat requirements, including soil textural traits, moisture, soil chemicals, soil type, and light levels, see Boyd and Hilton's (1994) study of a population of Clematis socialis.

Community quality

Managers at Eglin Air Force Base have developed a system to classify community quality (the "Ecological Tier System" in FNAI 1994a). This system has also been used recently at Camp Blanding, FL (FNAI and TNC 1995). Determination of community quality has obvious benefits for conservation planning. Low quality communities do not merit the same conservation status as higher quality communities and therefore should be treated differently in terms of protection, restoration efforts, and allowable land uses. Use of a quality ranking system for management can assure that protection priority is given to highest quality communities, because these are our best examples of natural species assemblages and other community attributes. Furthermore, use of this system can assure that restoration activities are used for communities that have the potential to become high quality with minimum restoration efforts. Restoration of such communities can enhance habitats that support TES. Similarly, use of a quality ranking system can ensure that efforts are not wasted in the restoration of low quality communities. Finally, plant communities on installations are subject to multiple land uses, and use of a quality-based ranking system, in combination with an assessment of impacts of various land uses, can allow managers to determine which activities are appropriate in which communities. The ranking system developed for Eglin AFB, FL, has been adapted for this report, with descriptive names given to each community quality type:

TYPE I - High quality community: "Portions of vegetative communities which are in or closely approximate their natural state. These areas have experienced relatively few disruptive events. Examples are areas of old growth or relatively undisturbed vegetation. Management activities should be predominantly in the maintenance category, utilizing methods that mimic natural formative forces such as prescribed fire" (FNAI 1994a).

TYPE II - Intermediate quality community: "Portions of vegetative communities that still retain a good representation and distribution of associated species and which have been exposed to moderate amounts and intensities of disruptive events.... These are areas where ecosystem function and viability can be restored through careful, responsible management. Management direction will integrate appropriate management activities to accomplish restoration and maintenance objectives. Restoration activities may include practices that will accelerate change in the desired direction (i.e. use of herbicides and/or mechanical methods of hardwood control, supplemental planting of longleaf seedlings, etc.)" (FNAI 1994a).

TYPE III - Moderately low quality community: "Portions of vegetative communities that do not retain a good representation and distribution of associated species and which have been exposed to severe amounts and intensities of disruptive events.... These are areas where restoration of ecosystem function and viability might be possible, but would require significant and intensive management commitment over extended periods of time. Depending on land-use priorities, management direction may encourage a return to a more natural vegetative association over the long term and/or may include intensive use of traditional management techniques" (FNAI 1994a).

TYPE IV - Lowest quality community: "...sites that either will not be or are not capable of being restored under any likely realistic scenario because of dedicated land use. Type IV areas include cleared test ranges, sewage disposal spray fields, urban areas, main roads, designated clay pits, power line rights-of-way, and possibly some wildland interface areas" (FNAI 1994a).

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